

Resource Management Committee

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**REPORT OF THE
WORKSHOP ON FLEKSIBEST – AN AGE AND LENGTH
BASED ASSESSMENT TOOL**

**Bergen, Norway
16–19 January 2001**

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1 INTRODUCTION

1.1 Participants

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1.2 Terms of reference

It was decided at the 88th Annual Science Conference in 2000 (C. Res. 2000/2D01) that:

A Workshop on FLEKSIBEST – an age and length based assessment tool (WKFLEK) (Chair: Dr. K. Guldbrandsen Frøysa, Norway) will be held in Bergen, Norway from 16-19 January 2001 to:

- a) define a protocol and workplan for testing the FLEKSIBEST model based on a review of the model and the results of runs made during and after the AFWG meeting in 2000. These results allow comparison of method performance;
- b) enable participants through hands-on exploration of FLEKSIBEST to contribute to the test and further development of the method;
- c) discuss the interpretation of results from FLEKSIBEST.

WKFLEK will report by 26 January 2001 for the attention of the Resource Management Committee and ACFM.

1.3 Background

In 1997, a research project for constructing a new assessment model for Northeast Arctic cod- FLEKSIBEST- was started at IMR, Bergen, Norway. A workshop on comparison of stock assessment model strategies, with application to Northeast Arctic cod, was held in December 1998 (Pennington, 1999). FLEKSIBEST was a main topic at that workshop. This model has been run as an auxiliary model for Northeast Arctic cod in addition to the 'standard' XSA assessment at the last two ordinary meetings of the ICES Arctic Fisheries Working Group (AFWG) (ICES CM 2000/ACFM:3; ICES CM 2001/ACFM:2), and will also be used at the next meeting of the AFWG (April/May 2001). As FLEKSIBEST is a model with a more complicated structure (age and length based) than assessment models presently in use by ICES Working Groups, it was found appropriate to arrange a workshop. The purpose of the Workshop was to contribute to the evaluation, testing and further development of the model.

1.4 Structure of the report

Relevant background information is given in Sections 2 and 3. Section 2 deals with existing assessment models and with some problems which have been encountered in the assessment of Northeast Arctic cod. Section 3 gives a description of FLEKSIBEST (model and data). In Section 4 the results of hands-on exploration of FLEKSIBEST (ToR b) are described. The interpretation of the results from actual FLEKSIBEST runs (ToR c) are also considered in this section. A more general discussion of how to interpret results from a model of this kind is given in Sections 5.1-5.4, and guidelines for future work are given in Section 6. These sections address the workplan request in ToR a). During the meeting, this request was redefined from definition of a workplan for testing of FLEKSIBEST to definition of tools and approaches for analysis of models of this kind. How a model (e.g. FLEKSIBEST) can be certified for use as an ICES stock assessment tool (ToR a) is described in Section 5.5.

1.5 Terminology

The word 'model' is used in three ways in the report:

- a) To describe a framework or toolbox for stock assessment (e.g. FLEKSIBEST);
- b) To describe a model in which sub-models for biological and fisheries processes are chosen, but without a set-up for which parameters to estimate and which to fix;
- c) An actual realisation of a model, with a data set and a choice of which parameters to fix and which to estimate.

2 ASSESSMENT MODELS

2.1 Existing models

Models applied to fish stock assessment may be structured in many ways, from biomass-based models to models where the population is structured by some or all of the variables age, length, sex and area. Here we will briefly mention some models that are structured by age and/or length.

The existing age-structured models used for fish stock assessment fall into two groups:

- a) VPA-type models where the catch-at-age is assumed to be exact, e.g. XSA (Shepherd, 1999) and ADAPT (Gavaris, 1988). In such models the stock abundance in numbers and the fishing mortalities are derived directly from catches-at-age. Relationships between abundance indices and stock abundance are used to calibrate such models.
- b) Statistical catch-at-age models. The characteristic feature of these models is that a self-contained population model is fitted to the data (catches, surveys), and that the catch-at-age is not assumed to be exact. Examples of such models are CAGEAN (Fournier and Archibald, 1982, Deriso et al., 1985) and ICA (Patterson and Melvin, 1996).

Length-based models are often used for species which are difficult to age. An example is the length-based assessment of the Northern shelf anglerfish conducted for the first time at the 2000 meeting of the Northern Shelf WG (ICES CM 2001/ACFM:01), as a comparison to the simple separable catch-at-age assessment, which had previously been used. The assessment used the size transition matrix model ideas of Sullivan *et al.* (1990).

Simulation models that are age- and length-structured have been formulated e.g. for boreal multispecies systems; MULTSPEC (Bogstad et al., 1997); BORMICON (Stefánsson and Pálsson, 1997; 1998). These were not made specifically for making assessments of the present stock size. However, the BORMICON model has been used in the assessment of Golden redfish (*Sebastes marinus*) in the Northwest Atlantic (ICES C.M. 2000/ACFM:15).

Age- and length structured models where the length structure is described by a probability distribution have also been presented (Deriso and Parma, 1988; DeLeo and Gatto, 1995).

2.2 Assessment of Northeast Arctic Cod

Northeast Arctic Cod has been assessed using the Extended Survivors Analysis (XSA) model for the past several years.

The assessment of this stock, however, has proven to be quite problematic over a considerable period for a variety of reasons. In particular, most assessments have underestimated fishing mortality and overestimated population size in the most recent year of the assessment data. Several particular concerns have been raised as follows:

- 1) The assumption of stock size dependence up to a certain age in survey indices has had a substantial impact on the results in many assessments. In the XSA a stock size dependence option is available, however, it has to be applied for the same age groups over all fleets used for VPA calibration. The AFWG has considered this to be a limitation as to how well the survey calibration data could be utilised.
- 2) There has been doubt about the reliability of the catch statistics, particularly with respect to discarding and under-reporting, which indicates that there is a need for alternative models, which do not assume that the catch data are correct.
- 3) In some years rapid changes in growth and maturation contributed strongly to “biased” predictions of stock size and catches.
- 4) Including cannibalism in the XSA assessment has required a laborious and time-consuming procedure of manual iterations.
- 5) Concerns about substantial influence from low and noisy values (due to log-transformation in XSA) have also been raised, however, this problem is not unique to NEA cod.

It is recognised that the main problems plaguing the assessment of NEA Cod relate both to the model formulation used and to the data and how they are interpreted. It is evident that there are periodic changes in the relationship between surveys and model-based stock estimates, which also could be associated with:

- Uncertain catch statistics;
- Changes in survey methodology;
- Unaccounted mortality due to sea mammal consumption of cod, which is indicated to vary with varying capelin stock abundance.

It was considered, therefore, that development of a more flexible assessment tool such as FLEKSIBEST would be helpful in addressing some of the concerns identified above.

3 FLEKSIBEST

3.1 Description

FLEKSIBEST (Frøysa *et al.*, 2001) is a computer program for an age- and length-structured fish stock assessment model. It has been applied to Northeast Arctic cod. It is essentially an age- and length-structured version of the ‘statistical catch-at-age analysis’ class of models. Length structure is included because most population dynamics processes are related to the size rather than the age of fish. For Northeast Arctic cod and many other fish stocks in boreal systems, age is not a good proxy for size. Such stocks experience large inter-annual variation in growth and thus in size-at-age (Mehl and Sunnanå, 1991).

In FLEKSIBEST, the immature and mature stock is modelled separately. Growth, maturation, natural mortality and fishing mortality are modelled as length-dependent processes. A model for predation mortality due to cannibalism is included. Each fleet has its own separate length-dependent selection. Annual recruitments are model parameters, which are estimated.

The abundance of a cohort in the first year of the time period also has to be estimated, together with annual fishing mortalities and survey catchabilities. Parameters describing annual growth rate, maturation fleet selection and cannibalism may either be determined externally or estimated by the model.

The model is fit to the data (survey abundance indices, commercial catch data, stomach content data from surveys) by minimising the discrepancy between modelled and observed values, based on likelihood-type approaches.

FLEKSIBEST is based on the Icelandic multi-species, multi-area model BORMICON (Stefánsson and Pálsson, 1997; 1998) and shares much of the same program code and functionality. The main modifications are the change from a multi-species, multi-area model to a single-species, single-area application. FLEKSIBEST and its associated programs run under Unix and Linux. Since Linux is freely available for PC and Macintosh computers the software will run on almost all computer platforms, and can run within Windows using a Unix emulation program.

3.2 Data used

FLEKSIBEST uses survey abundance indices, data from commercial catches and stomach content data from scientific surveys. Commercial CPUE data are not used at present, but will fit into the model. The data used are calculated in the same way as those used in the standard age-based assessment, but they are not aggregated over length groups before being used by the model. The model can be run on any age range desired. The runs presented in this report cover the age range 3-12+. The model was run over the time period 1983 (first quarter)-2000 (first quarter), which is the period when data are currently available.

3.2.1 Survey abundance indices

FLEKSIBEST uses abundance indices by age and length from the following surveys:

1. Norwegian winter (February) survey in the Barents Sea – bottom trawl indices (Jakobsen et al., 1997);
2. Norwegian winter (February) survey in the Barents Sea – acoustic indices (Jakobsen et al., 1997);
3. Lofoten acoustic survey (March/April) (Korsbrekke, 1997);
4. Russian autumn (October/December) bottom trawl survey in the Barents Sea (Lepesevich and Shevelev, 1997);
5. Norwegian summer (July/August) survey in the Barents Sea – bottom trawl indices (Aglen, 1999).

Also, annual weight-at-length data from surveys 1 and 3 have been used in calculations of biomass, but not in fitting model to data.

The age and length range for which the survey data are used in the model runs presented in Chapter 4 are described in the text table below. The stock(s) each survey is assumed to cover (immature/mature/both) is also given, together with the time period for which data are available. Data are given on 5 cm length groups:

Survey	Age (years)	Length (cm)	Time period	Stock covered
1	3-10	20-90	1983-1993, 1994-2000	Immature
2	3-10	20-90	1983-1993, 1994-2000	Immature
3	5-12	55-110	1985-2000	Mature
4	3-12	5-110	1983-1999	Both
5	3-12	5-110	1995-1999	Both

The time series for surveys 1 and 2 are split in two periods (1983-1993, 1994-2000) because of the change of gear and increase in area coverage in 1994 (Jakobsen *et al.*, 1997). The indices from surveys 1 and 2 (carried out at the same time) are correlated. One of the reasons for this is that in general the same length and age samples are used in calculation of both indices.

Much work has been done on attempting to quantify the uncertainty of the Norwegian survey estimates. One example of quantification of uncertainty, which could be utilised in FLEKSIBEST, is from the Norwegian bottom trawl winter survey (1), where the coefficient of variation for the number of fish in each 5 cm length group is given in the survey report (Mehl, 1999).

3.2.2 Commercial catch data

The catch in numbers-at-age and length for each year and quarter for the following fleets is available:

Norway: Danish seine, gillnet, handline, longline and trawl;
Russia: trawl.

These fleets account for 85-90 % of the reported catch. From third countries, catch in tonnes, but not age-length data, are currently available.

Data for all fleets are given on 5 cm length groups for ages 3-12+ and length groups 5-135 cm. Data are available for 1983 and 1985-1999. All fleets are assumed to fish both on immature and mature fish.

Work on quantification of uncertainty in catch data is in progress, but no results are available yet.

3.2.3 Stomach content data

Stomach content data for cod are collected annually on Norwegian and Russian surveys for demersal fish. The methodology is described in Mehl and Yaragina (1992). In order to compare data on the abundance of cod prey in cod stomachs with the mortality induced by the cannibalism model in FLEKSIBEST, a gastric evacuation rate model (dos Santos and Jobling, 1995) was combined with the stomach content data. The consumption (kg/time step) of cod by cod (cannibalism), by prey length group and predator age group, was then calculated in the same way as in Bogstad and Mehl (1997). No attempts have been made to quantify the uncertainty in the stomach content data or the calculated consumption.

Data are available for 1984-1999, on predator age groups 3-9+ and on 5 or 10 cm wide prey length groups. The data have been calculated on a half-year basis, but are for this purpose distributed evenly on the two quarters within a half-year.

In the model it is assumed that both mature and immature cod are predators on immature cod.

3.2.4 Biomass of alternative prey

The model for cannibalism in FLEKSIBEST takes into account the biomass of alternative prey. Capelin is the main prey item for cod (Bogstad and Mehl, 1997), and quarterly abundance estimates of capelin biomass based on annual acoustic abundance estimates (Gjøsæter *et al.* 1998) and assumptions about growth, natural mortality and fishing mortality are used to represent the abundance of alternative prey.

3.3 Fitting model to data

Within FLEKSIBEST, there is an age-length structured model and three separate sources of data, which are formally linked through an objective function. The objective function must minimise the difference between model predictions and observed data.

Data sources

The data sources used in FLEKSIBEST are:

- commercial catch data;
- survey data; and
- stomach content data.

There may be several fishing fleets and surveys, but it is assumed that all the data sources are independent. The three sources of data are used for parameter estimation within FLEKSIBEST. The model data are age-length structured data from commercial catches and surveys, and calculated consumption derived from stomach content data (Section 3.2.3).

Objective function

An objective function is defined to compare observed and modelled values. The overall objective function is a sum of partial objective functions, each representing the comparison of a certain data set (commercial catch, survey, consumption), and there is limited flexibility in the choice of what to include, and which parameters to optimise and constrain. A component of the objective function is also employed to prescribe upper and lower bounds on variables to be estimated. Parameters exceeding their pre-set bounds contribute a very large value to this component.

A limited selection of objective functions (Pearson, Gamma), and of aggregation levels at which model and data are compared, are currently implemented. The choice of objective function can be critical to the solutions obtained.

Common practise is to derive objective functions as likelihood functions based upon distribution assumptions. Formulation of the objective function as a likelihood function has the additional benefit of producing measures of precision (dispersion, asymptotic standard errors) for optimised (unconstrained) parameters. However, estimates of precision are not yet implemented within FLEKSIBEST.

Initial conditions

Typically, one may want to estimate 150-200 parameters and treat as fixed 200-300 parameters. No documentation is available on the choice of either suitable starting values to adopt or bounds to impose on the solution space. The selection of initial parameter values will be time consuming and may be prohibitive for some applications. There is no simple basis for the choice of either the weighting of observations or the weighting of components within the objective function. The specification of relative weights cannot be accomplished automatically and the results can be sensitive to the values for such weights.

Optimisation

Currently two minimisation algorithms are implemented within the program – a direct search algorithm and simulated annealing, although the latter is currently not used in FLEKSIBEST. The numerical routine used for optimisation of the objective function is based upon the direct search algorithm of Hooke and Jeeves (1961). This has the advantage of being robust but is generally slow for large numbers of parameters.

The following suggestions were made during the sub-group discussions:

- The data available for assessment purposes and the range of plausible relationships between these data and the quantities included in the model need to be specified.
- It was suggested that the model should be written to be formally independent of the data. Currently, the model may incorporate assumptions based on *external* data (e.g. growth rates), ideally these should be subject to rigorous examination.
- Alternative objective functions and optimisation routines will be needed. There appears to be a lack of statistical rigour in the choices implemented for the example considered during the Workshop.
- Uncertainty estimates are not provided at present but techniques and algorithms to provide these will be needed in the future.
- Measures of goodness-of-fit need to be identified for components of the model. In addition, diagnostics need to be provided for components within the objective function.

These issues are currently being addressed within a project entitled: *Development of structurally detailed statistically testable models of marine populations* (DST²). This is a four-year funded project under the EU Framework V Programme (QLRT-1999-01609), which started in February 2000. It is a collaborative initiative between eight partners - MRI, Iceland; IMR, Norway; DIFRES, Denmark; SCUI, Iceland; UiB, Norway; FRS, UK(Scotland); CEFAS, UK(England & Wales); and IFREMER, France.

3.4 Discussion of model assumptions.

The assumptions made within the FLEKSIBEST initial run for the Northeast Arctic cod were examined. These fall into two categories related to models that describe the dynamics of the stock and those for the dynamics of the fishery. The Workshop reviewed the structure of the formulations and the constraining assumptions but could not verify them. The diagnostics produced by FLEKSIBEST are currently insufficient to allow an evaluation of the precision of the numerical estimates at the "converged" solutions, the correlation between parameters or the testing of departures from the assumptions.

Exploratory runs carried out at the Workshop (Section 4) highlighted the sensitivity of the model and absence of analytical diagnostics for model evaluation. It was noted that relatively minor variations of the starting values provided

for the estimated parameters, resulted in relatively large variations in the final "converged" parameter estimates. This was achieved with only minor differences in the objective function value. This relatively simple sensitivity analysis suggests that the numerically estimated solution is not well defined and consequently the parameter values are poorly determined.

Concerns were raised that the initial model structure for the Northeast Arctic cod may be poorly parameterised and that externally fitted, constrained parameters may have a greater influence on the final solution than many of those included within the minimisation. The sensitivity of the initial model parameter estimates to one such parameter, the coefficient of consumption, was examined. When estimated by the program, the model estimated value was half of the constraint value and there was a substantial increase in the estimated catch biomass in the most recent years. The run confirms the influence of the externally estimated consumption parameter and indicates that it should be included within the model formulation and estimated within an extension of the objective function.

The Workshop noted from the FLEKSIBEST results presented in the AFWG Report (ICES CM 2001/ACFM:02, Figures 3.10 and 3.12d), that catch numbers at age in each year of the model fit appear to be well estimated; this contrasts with an over-estimation of catch biomass. The Workshop suggested that the estimated and observed values of weight at length be examined in order to validate the assumptions made within the growth formulations.

The initial model formulation for the Northeast Arctic cod selection-at-length was discussed and considered to be too restrictive for the modelling of the fishing fleets. Concerns were raised that a flat-topped selection pattern was being imposed on the fleet selection and a more flexible formulation, such as the "bell-shaped" model, should be examined to allow for the possibility of a decline in selection at longer lengths.

In addition the following suggestions were made:

- That the diagnostics for the model should be given a high priority so that model and assumption testing and evaluation can be carried out (Ref. Section 5).
- Recruitment is provided only as the number of recruits. There is no process model for either recruitment or the development of early life-history stages. Such processes should be investigated.
- A link between spawning stock biomass and recruitment needs to be investigated.

4 EXPLORATORY RUNS

A few exploratory runs were made. Some selected results were presented and discussed. This is summarized below.

Initial run

Appendix 1 specifies parameters, their starting values, optimization switch (1="on", 0="off"), and the result of the optimization. Tables 4.1-13 show the resulting stock estimates.

A useful evaluation of the estimated parameters and overall results has to include a close inspection of how modelled values compare to the observations, such as survey estimates by length or age, each fleets' catch by length or age, and consumption by length or age. Such comparisons should particularly aim to detect possible violations of the model assumptions.

Since programs presenting convenient comparisons were not easily available, just two examples of detailed comparisons were made; modelled and observed survey values by length for the Russian bottom trawl survey and for the Norwegian bottom trawl winter survey.

A poor fit was observed for the Russian survey. For this survey the estimated value of L50 in the selection function was equal to the lower bound specified. The patterns shown in Figure 4.1 illustrate that for this survey the selection for small fish is estimated to be too high by the model. By accident the initial value had been set at the lower bound. It was not further explored whether a more realistic starting value would change the result. Figure 4.2 shows a reasonable pattern for the Norwegian bottom trawl winter survey, but some variation between years is evident.

Initial run with altered starting values

To test whether the result could depend on parameter starting values, the starting values were changed for 15 of the parameters to be estimated (Appendix 2). Those parameters were: annual growth for the years 1983-1987, number of immature 3-year-olds in start-year, recruitment in 1986, 1989, 1993 and 1994, and mean length of recruits in 1985-1989.

The program was run to the chosen convergence criteria. The final likelihood value for this run was 6 647 422, compared to 7 105 477 for the initial run.

Some changes in final results were observed (Figures 4.3-6). This was most pronounced for the spawning stock biomass, less for catches and total biomass, and rather marginal changes were observed for fishing mortality.

Initial run without optimization of yearly growth rate

Yearly growth rates were set as estimated by the initial run and a new run was made with all other settings as in the initial run. The results (Figures 4.7-10) show a small increase in recruitment over the whole time series, some increase in catch and biomass before 1995 and some differences in F , variable in time.

Initial run + optimizing consumption

The alpha in the consumption equation (cann_alpha) was added as the 177th variable in a run and results were compared to results from the initial run with 176 variables. The final likelihood value for this run was 6 934 705. In the initial run the value for alpha was fixed at 7.0e-06 while the value reached after optimizing was reduced to 2.4178e-06. This resulted in a 10-30% increase in spawning stock biomass (SSB) in the 90s (Figure 4.11). Also catches increase especially in 1994 (Figure 4.12). The M_2 (predation mortality) is reduced to 50% of the value of the initial run for 3 and 4-year-old cod (Figure 4.13).

5 TESTING AND EVALUATING OF FLEKSIBEST

5.1 Introduction

In this section a certain number of issues related to testing and evaluating parameter estimates obtained with FLEKSIBEST are raised. Methods for investigating the success of the estimation procedure are dealt with. This includes the exploration of the sensitivity of final results to starting values. Some diagnostics for assessing the model fit for given model and data sets are proposed, and sensitivity of estimates to a change in values of fixed parameters and model misspecification are considered.

These investigations are for a given model formulation, which includes the actual functional forms as well as what parameters are fixed and which ones are estimated within FLEKSIBEST. Strategies for model building are considered in the following section.

5.2 Model building

Model building aims at identifying models that are parsimonious in their number of parameters. This may be achieved by systematically adding variables to a minimal basic starting model, and identifying those which give the greatest improvement in model accuracy, and allowing the rejection of redundant or minimally useful components. In a complex model such as FLEKSIBEST the number of possible permutations of model components is extremely large, therefore a method is needed to rapidly assess the potential contribution of different model components, and easily identify which ones are worth considering further.

The model produces values for objective functions comparing the output of the model to various data sets, and an overall summary objective score. These objective values provide an ideal tool for a first assessment of the utility of different combinations of model components. As an example Table 5.1 indicates the objective scores for a simple single-species, single-area BORMICON model, and the improvement obtained by allowing different parameters, mean length of recruits, growth rate k in von Bertalanffy growth function, and fleet selectivity curve, to vary on an annual basis or to introduce variability of the length of recruits around the mean value. Each component is shown as a percentage of the objective value of the original model run. It can be easily seen that either allowing for annual changes in mean length of recruited fish, or growth rates, produces a noticeable (about 12%) improvement to the model fit, while introducing variability in length of recruits produces a much smaller (5%) improvement. This can be extended to

combinations of different variables, and should lead to a rapid elimination of redundant terms. FLEKSIBEST is a derivative of the BORMICON model, and thus this approach should translate well between the two models.

Analysis of different objective components can also be used to investigate model behaviour, identifying areas of the model which are performing well, and which are doing less well. In the example below the length distribution in the catch behaves differently from the other components. This highlights a possible problem in the model formulation for commercial catches.

It is suggested that an approach such as this should be employed as a first step in identifying which model components provide a significant contribution to the process description, and as an investigative tool in understanding and exploring the model behaviour.

Table 5.1. Changes (in %) in the objective components due to different changes in the model formulation. Results were obtained using BORMICON for a haddock example.

Component	Annual recruit length % of ORIG	Annual growth rate % of ORIG	Variability in recruit lengths % of ORIG	Catch selectivity % of ORIG
Overall Objective score	0,90	0,91	0,98	0,96
% of original value	88,04	88,50	95,37	93,82
mean length in survey	76,16	63,80	99,46	101,47
mean length in catch	78,66	74,47	98,94	94,11
Length distribution in survey	78,13	98,41	87,09	98,92
Length distribution in catch	101,77	100,59	100,42	82,48
age-length key: survey	76,72	77,25	96,52	101,57
age-length key: catch	93,27	92,96	99,06	101,26
Survey index: 10cm	41,22	120,50	2,63	101,94
Survey index: 15cm	80,80	71,05	95,70	102,70
Survey index: 20cm	80,38	87,73	100,96	99,02
Survey index: 25-45cm	74,77	58,22	94,23	98,58
Survey index: 50-60cm	105,66	84,05	99,17	105,59
Survey index: 65-75cm	98,09	114,02	101,31	89,20
Nvpa	60,10	68,78	99,45	81,07

5.3 Evaluating model fit for selected model

For a particular model, it is important to be able to assess whether this chosen model is appropriate given the observed data and assumptions, e.g. fixed parameters and boundary constraints. The main objective is therefore to detect any systematic failures or weaknesses of the model and its assumptions. This is an important stage in the testing of any model, but becomes a significant task when the model is as complex as that used in FLEKSIBEST. Visual diagnostics may be useful as a first step, but should be followed up by a more rigorous numerical analysis. The group proposed the following suggestions as a first approach.

After convergence, the routine outputs the number of steps required by the search algorithm to converge on the optimum solution as well as the initial and final values of the objective function. A further useful output would be a list of those parameter estimates that lie on their boundary and a list of names of those parameters. Parameters lying on their boundaries may indicate incorrect model assumptions or parameter constraints.

As a first step in evaluating the fit of a particular model, a visual comparison of predicted and observed quantities (those used in the objective function) should be conducted. In the case of a FLEKSIBEST run, the following data should be checked by quarter and year:

- catch (in numbers) by fleet vs length
- catch (in numbers) by fleet vs age

- survey indices (in numbers) by survey type vs length
- survey indices (in numbers) by survey type vs age
- consumption by age of predator for length of prey.

The plots suggested above may be useful in helping decide where further investigations could be concentrated, but a more formal analysis should be conducted to detect where any systematic errors occur. Residuals from all components in the objective function should be analysed (by ANOVA, for example) to detect the effects of the type of data (e.g. survey), age, length groups, years and quarters on these residuals. Any such effects might indicate the part of the model, which gives systematically erroneous estimates.

Further residual plots should be used to check the validity of assumptions. For example, checking whether any trend can be detected in residuals (plot of residuals vs. time if the model assumes a particular parameter to be constant over time).

Data that is external to the objective function could also be compared with estimates of these variables obtained from the model. For example:

- growth rates by length group and year for mature and immature individuals
- maturity at length by year
- mean length in surveys per year, in catch per year, per age and year and fleet
- mean weight at age in surveys per year
- mean weight at length in surveys per year.

An essential component of model evaluation is the consideration of the variance-covariance matrix in order to identify which parameters are ill-defined.

In FLEKSIBEST, the variance-covariance matrix will have large dimensions, which makes a visual approach for studying them virtually impossible. Therefore some other analyses of these matrices might be carried out. One example would be lists of highly correlated parameters and badly estimated parameters (those with high variance).

5.4 Sensitivity analysis

All parameter estimates are conditional on the model formulation and the values of fixed parameters. For assessing the effect of the chosen fixed parameter values and model formulation, sensitivity analyses should be carried out. In the following an outline is given how the sensitivity of parameter estimates to fixed parameter values can be investigated using simulated data. A similar approach can be used for real data.

For any given model with a set of fixed parameters and the simulated data (population numbers, catches, survey indices, stomach data, etc.), all fixed parameters have to be varied in a systematic way. A factorial design is most suited for this. Given there are a large number of fixed parameters, say nf , those most influential have to be identified in order to reduce the task to a manageable size. The different steps involved in the analysis would be: i) to create g groups of independent parameters making sure all important parameters are included, ii) carry out estimation varying fixed parameters one group at a time (for example +10% and -10% of original values), iii) analyse estimated parameter matrix ($nf \times g$) and estimated population numbers at age and length by time matrix. Statistical analysis of the results matrices should lead to identification of the important parameter groups and to a quantification of the associated changes in parameter estimates. The sensitivity of population estimates to fixed parameter values is also obtained.

Robustness of parameter estimates to violations of model assumptions or errors in the data can be investigated in a similar manner. For these investigations the simulated data has to come from a model that is different from the model used for estimation.

5.5 Certification of ICES stock assessment tools

If FLEKSIBEST is to be a candidate for an ICES stock assessment tool, then the program needs to be certified and thoroughly tested.

Any analytical software used by ICES assessment working groups has to undergo a defined testing process in order to ensure quality and efficiency (ICES CM 1999/ACFM:25, working document ACFM May 2000, Certification of software used for assessment purposes). Other tools will only be used if the standard library does not provide the necessary method. New programs must be judged against a number of criteria to gauge their suitability for adoption as standard assessment software. It will be necessary to ensure that new software tools as well as the methods they are based on are adequately tested. It is desirable that the testing includes some form of Monte Carlo testing, e. g., using simulated data with known error distributions to verify that the program returns unbiased estimates of the population parameters (ICES CM 1999/ACFM:25). Standardisation of inputs and outputs are part of making a tool suitable for routine ICES stock assessments. In addition, in order to standardise the comparison of methods, the following list has been proposed as a minimum requirement (Patterson, 2000):

- Robustness of assessments to alternative assumptions or data series
- Parameter uncertainty, possibly as confidence intervals
- Illustration of conflicts in data series.

The Workshop did not discuss whether the standard library of assessment models available at ICES provides the necessary method for assessment of Northeast Arctic cod.

6 FURTHER WORK

6.1 Northeast Arctic cod application

FLEKSIBEST is designed as a single-species application for Northeast Arctic cod. Some of the fishery and stock characteristics are in favour of using a single-species model, but there are a number of multispecies issues, which address the use of more integrated assessment models.

6.1.1 Stock components

For assessment the Northeast Arctic cod population in ICES areas I and II is at present defined as a single stock unit. This seems to be sufficient for single species assessment for the time being, but on the other hand there are concerns regarding the relationships between various stock components in the area. For assessment purposes stock boundaries should be clearly defined, but at present the extent of intermixing of various cod stock components is largely unclear.

6.1.2 Fishing fleets

The fishery for Northeast Arctic cod is conducted both by an international trawler fleet operating in offshore waters and by vessels using gillnets, long lines, hand lines, and Danish seine operating both offshore and in the coastal areas. Fishing fleets provide important input data to FLEKSIBEST. However, caution is advised in how to aggregate fishing fleet information for the modelling purposes, in particular because the operation of the fleets may exploit various stock components in different quarters of the year, depending on spatial and temporal fish distribution patterns.

6.1.3 Ecosystem aspects to be considered in the assessments

Considerable effort has been devoted to investigating multispecies interactions in the Northeast Arctic. Some of these investigations have reached the stage where some quantitative results are available for use in assessments. When making a choice to use either a single-species model like FLEKSIBEST or a multispecies model like BORMICON for Northeast Arctic cod stock assessment, the following matters should be considered:

The growth of cod depends on the availability of prey, and variability in cod growth can significantly impact the fishery.

The timing of cod spawning migrations is influenced by the presence of spawning herring in the relevant area.

The annual consumption of herring, capelin, and cod by marine mammals has been estimated to be in the order of 1.5-2.0 million t.

The recent estimate of total annual food consumption of Barents Sea harp seals has been estimated to be in the range of about 3.3-5.0 million t (ICES C.M. 2001/ACFM:08).

If capelin was abundant, the total harp seal consumption was estimated to be about 3.3 million t, of which capelin was approximately 800 000 t, polar cod 600 000 t, herring about 200 000 t and Atlantic cod 100 000 t.

- A low capelin stock in the Barents Sea (as in 1993-1996) led to switches in seal diet composition and they consumed approximately 870 000 t of polar cod, other cod fishes (mainly Atlantic cod) about 360 000 t, and herring about 390 000 t.
- The composition and distribution of species in the Barents Sea is dependent on the position of the polar front which separates warm and salty Atlantic waters from colder and fresher waters of Arctic origin.
- Variation in the recruitment of cod and capelin, for example, is associated with the changes in the influx of Atlantic waters to the large areas of the Barents Sea shelf.

6.2 FLEKSIBEST program

6.2.1 Issues to be addressed in further work with FLEKSIBEST

This is a summary of suggestions made in Sections 3, 4 and 5.

- Guidelines for how to choose the initial parameter values and parameter bounds.
- Guidelines for how to weight the different terms in the objective function.
- Exploration of objective functions and optimisation routines is needed.
- A statistical justification for the choices of objective function must be given.
- Uncertainty estimates need to be provided.
- Measures of goodness-of-fit and diagnostics need to be provided for components within the objective function.
- Diagnostic tools for comparisons of modelled and observed data, both observed data used in the objective function and observations not used directly in the objective function, e.g. mean length-at-age.
- Ability to rapidly assess the potential contributions of different model components to the objective function.
- Making a minimal basic starting model to facilitate model building.
- A summary file on the optimisation, giving the initial and final values of the objective function, a list of the parameters that reached their boundary value (and the value) and the convergence criteria.
- Tools for residual analysis and residual plots must be provided.
- Sensitivity tests with respect to fixed parameters.
- Test of the robustness of parameter estimation results with respect to the initial parameter values.

6.2.2 Optimisation algorithm issues

The efficiency and success of the numerical optimisation algorithm should also be further tested. At present the optimisation is carried out using a direct search algorithm (Hooke and Jeeves, 1961), but other algorithms could be implemented, the code already allows for the implementation of simulated annealing. By using a data set which has

been simulated and therefore has known properties, the features of these algorithms can be further investigated. In theory, refitting the model to the simulated data should result in the same parameter values. Tests could be carried out to investigate if, and after how many iterations, the expected parameter values are obtained if, for example, the parameters to be optimised are given different starting values or if the convergence criteria is altered. A short summary file giving the number of steps required in the routine, initial and final values of the objective function and convergence criteria would be a useful standard output.

6.3 Practical concerns for the use of FLEKSIBEST

6.3.1 Introduction

A distinction needs to be drawn between the FLEKSIBEST modelling program itself and the user interface for running the program and interpreting the results. Separate programs can be created to ease the configuration and running of FLEKSIBEST, and to facilitate the interpretation of model results and formulation. These accessory programs are of considerable importance in influencing the practical value of the system. Some work has already been done in developing these programs, but more is needed to ensure the maximum utility of FLEKSIBEST.

6.3.2 Configuring and running the program

FLEKSIBEST is a complex and flexible program, and as such can never be entirely straightforward to use. Files need to be constructed to control both the configuration of the model and the datasets used in the objective functions. The format of the control files is logical, but not well documented, and it would be of use to have a clear and concise guide to interpreting and modifying these files. In particular, documentation of any particular model formulation should be included as well as overall documentation of the system. A guide to the selection of initial values and bounds for estimated parameters and values for fixed parameters should also be provided.

Constructing the data files is at present a major challenge. Work is ongoing in the DST² project (see Section 3.3) to address this by means of a data warehouse capable of automatically generating the required files from the underlying datasets. This is a major project, and should considerably reduce the effort required to set up a new model.

6.3.3 Results

There is considerable scope for improvements in presentation of the model results, which would drastically increase the utility of the system. A number of diagnostics have been suggested for the model output (Section 5.3) and the details of the optimisation process (Section 6.2), which it would be desirable to produce automatically. Any such outputs must be accessible and fully documented. A further useful utility would allow summary graphs to be produced of any of the model parameters, along with observed data where applicable. A prototype of such a system already exists, and could be extended in flexibility and utility. There is a trade-off here between ease of use and flexibility. A truly easy to use system would only be possible for a specific model formulation, while a more generalised system encompassing all possible model formulations would require more user input at run time. It would be desirable that standard diagnostics would be available for all models, while more detailed outputs may be available for specific models.

6.3.4 Overall ease-of-use issues

The possibility of constructing a single program to incorporate FLEKSIBEST and the ancillary programs, and present them to the user in a single coherent interface should be investigated. The specification of any such system requires careful thought. For development purposes full flexibility is required, however in practical terms many runs will be made on similarly configured models. A simple check that common features of all these runs are properly implemented each time would therefore be useful.

Documentation exists for the BORMICON family of modelling programs in general, however there is a need for documentation of specific examples, both for training purposes and before presenting model results to a formal body (such as ICES). Work is in progress to address this need.

6.3.5 Computing time

The present model formulation requires several hours for an optimisation run on a moderate specification computer, and around one hour for a high specification machine. This is acceptable for a single optimised run, but makes development and testing of the model inconvenient. Run times would inevitably increase further with any change to multi-species or multi-area models. Run times may be decreased by reducing the number of variables, or running the program in parallel

over several machines. It has also been noted that the optimisation may get close to the final solution in less than half the total iterations. In this case it may be worth running the model using a coarser convergence criteria – at least for initial diagnostic runs. There is also a possibility that optimisation of parts of the program may result in significant benefits. At present very little work has been done in this area, and further investigations are required.

7 RECOMMENDATIONS

A study group should be convened for four days in early 2002 in Bergen (Chair: Dr Kristin Guldbrandsen Frøysa, Norway) to investigate process model formulations, goodness of fit and model sensitivity in age-length based models, using tools such as FLEKSIBEST.

Suggested terms of reference:

- a) Investigate process model formulations, goodness of fit and model sensitivity in age-length based models, using tools such as FLEKSIBEST. The study group should consider specific case studies on ground fish, flatfish and pelagic fish stocks together with simulated datasets with known properties such as ageing errors.

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Table 4.1

runid BUN28680 Wed Jan 17 09:27:23 2001

stocks cod.imm cod.mat

areas 0

Total fishing mortality at age

Year	1983	1984	1985
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Age			
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3	0.0317	0.0461	0.0464
4	0.1557	0.1334	0.1558
5	0.3253	0.3249	0.2795
6	0.5589	0.5089	0.4619
7	0.7689	0.6905	0.5847
8	0.7898	0.7962	0.6370
9	0.7600	0.7781	0.6272
10	0.7536	0.7326	0.5935
11	0.7294	0.7134	0.5513
12+	0.7047	0.6821	0.5212
F 5-10	0.6594	0.6385	0.5306

Total fishing mortality at age

Year	1986	1987	1988	1989	1990	1991	1992
------	------	------	------	------	------	------	------

Age							
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3	0.0424	0.0395	0.0388	0.0389	0.0398	0.0594	0.0595
4	0.2046	0.1667	0.1117	0.1099	0.0954	0.1160	0.1211
5	0.4128	0.4360	0.2761	0.1854	0.1399	0.1806	0.1779
6	0.5659	0.6656	0.4968	0.2899	0.1668	0.2135	0.2330
7	0.7168	0.7921	0.6643	0.4053	0.1930	0.2303	0.2555
8	0.7766	0.8786	0.7538	0.4859	0.2109	0.2441	0.2648
9	0.7814	0.8960	0.8050	0.5199	0.2169	0.2502	0.2699
10	0.7569	0.8873	0.8042	0.5253	0.2168	0.2495	0.2693
11	0.7321	0.8670	0.7848	0.5104	0.2130	0.2463	0.2652
12+	0.7015	0.8493	0.7446	0.4695	0.2062	0.2383	0.2582
F 5-10	0.6684	0.7593	0.6334	0.4020	0.1907	0.2280	0.2451

Total fishing mortality at age

Year	1993	1994	1995	1996	1997	1998	1999	1997-1999
------	------	------	------	------	------	------	------	-----------

Age								
-----	--	--	--	--	--	--	--	--

3	0.0259	0.0245	0.0300	0.0279	0.0425	0.0529	0.0274	0.0409
4	0.1114	0.1334	0.1421	0.1611	0.2076	0.2699	0.1872	0.2216
5	0.1801	0.2989	0.3682	0.3708	0.4590	0.5297	0.4326	0.4738
6	0.2340	0.3929	0.5673	0.5861	0.6600	0.7422	0.6123	0.6715
7	0.2860	0.4538	0.6744	0.7217	0.8120	0.8694	0.7489	0.8101
8	0.3054	0.5052	0.7367	0.7814	0.8777	0.9310	0.8180	0.8756
9	0.3119	0.5169	0.7795	0.8025	0.8918	0.9364	0.8322	0.8868
10	0.3135	0.5176	0.7763	0.8047	0.8830	0.9274	0.8175	0.8760
11	0.3091	0.5129	0.7649	0.7897	0.8590	0.9125	0.8017	0.8577
12+	0.2995	0.4991	0.7354	0.7571	0.8151	0.8737	0.7667	0.8185
F 5-10	0.2718	0.4475	0.6504	0.6779	0.7639	0.8227	0.7102	

Table 4.2

runid BUN28680 Wed Jan 17 09:27:23 2001

stocks cod.imm cod.mat

areas 0

Residual natural mortality (M1)

Year 1983 1984 1985

Age

3	0.2000	0.2000	0.2000
4	0.2000	0.2000	0.2000
5	0.2000	0.2000	0.2000
6	0.2000	0.2000	0.2000
7	0.2000	0.2000	0.2000
8	0.2000	0.2000	0.2000
9	0.2000	0.2000	0.2000
10	0.2000	0.2000	0.2000
11	0.2000	0.2000	0.2000
12+	0.2000	0.2000	0.2000

Residual natural mortality (M1)

Year 1986 1987 1988 1989 1990 1991 1992

Age

3	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
4	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
5	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
6	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
7	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
8	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
9	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
10	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
11	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
12+	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000

Residual natural mortality (M1)

Year 1993 1994 1995 1996 1997 1998 1999 1997-1999

Age

3	0.2000	0.1999	0.1999	0.2000	0.2000	0.2000	0.2000	0.2000
4	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
5	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
6	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
7	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
8	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
9	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
10	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
11	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
12+	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000

Predation mortality (M2)

Year 1983 1984 1985

Age

3	0.0629	0.0480	0.0640
4	0.0130	0.0200	0.0216

Predation mortality (M2)

Year 1986 1987 1988 1989 1990 1991 1992

Age

3	0.1323	0.1535	0.0721	0.0623	0.0736	0.0759	0.1096
4	0.0344	0.0498	0.0293	0.0174	0.0107	0.0287	0.0420

Predation mortality (M2)

Year 1993 1994 1995 1996 1997 1998 1999 1997-1999

Age

3	0.2526	0.5035	0.5762	0.3961	0.2429	0.1410	0.0971	0.1603
4	0.0939	0.1791	0.1965	0.1391	0.1004	0.0586	0.0388	0.0659

Table 4.3

runid BUN28680 Wed Jan 17 09:27:23 2001

stocks cod.imm cod.mat

areas 0

Stock numbers (thousands) at age by Jan. 1

Year	1983	1984	1985	1986
Age				
3	301259	554294	614201	1164450
4	159374	224377	413064	450296
5	104664	110135	157470	282991
6	51347	61803	64944	96730
7	43141	24004	30403	33462
8	43789	16368	9846	13869
9	6125	16273	6045	4263
10	1100	2343	6137	2652
11	500	424	904	2766
12+	200	278	285	565
Total	711499	1010300	1303299	2052045

Stock numbers (thousands) at age by Jan. 1

Year	1987	1988	1989	1990	1991	1992	1993
Age							
3	355170	262487	195273	312668	714770	1020557	1594098
4	800621	239767	192334	144490	228533	511145	705550
5	289877	525787	169794	138585	106364	161775	355032
6	151654	151112	323289	114618	98360	72419	109132
7	44802	63479	74983	197505	79322	64990	46879
8	13371	16577	26695	40893	133261	51562	41188
9	5223	4545	6378	13439	27110	85456	32375
10	1599	1748	1667	3110	8884	17344	53553
11	1018	537	636	801	2022	5604	10664
12+	1319	812	516	577	914	1884	4711
Total	1664653	1266850	991566	966686	1399539	1992735	2953181

Stock numbers (thousands) at age by Jan. 1

Year	1994	1995	1996	1997	1998	1999	2000
Age							
3	1053674	637471	359254	594498	833419	510360	581379
4	987981	508730	284306	192403	365858	562018	368907
5	469822	590732	296032	171973	115519	215194	366090
6	234630	269239	313155	159217	85981	54385	112573
7	69814	127235	122580	140569	66620	33259	23989
8	28796	36050	52767	48583	50987	22825	12854
9	24836	14216	14095	19757	16529	16450	8244
10	20099	12398	5413	5190	6655	5321	5870
11	31319	9527	4594	1961	1732	2139	1913
12+	9268	19959	11463	6109	2894	1558	1378
Total	2930238	2225557	1463658	1340260	1546193	1423510	1483197

Table 4.4

runid BUN28680 Wed Jan 17 09:27:23 2001

stocks cod.imm cod.mat

areas 0

Spawning stock biomass (t) at Jan. 1

Year	1983	1984
------	------	------

Age		
-----	--	--

4	12342	0
5	16885	20990
6	52559	31327
7	122418	44799
8	186700	76432
9	39916	113209
10	10944	23861
11	5754	5372
12+	2654	4300
SSB total	450171	320287

Spawning stock biomass (t) at Jan. 1

Year	1985	1986	1987	1988	1989	1990	1991	1992
------	------	------	------	------	------	------	------	------

Age								
-----	--	--	--	--	--	--	--	--

4	0	0	0	0	0	0	0	0
5	24718	37362	24281	18105	5630	20265	25388	43684
6	57778	52246	73816	41787	58403	44378	75021	73858
7	63283	61943	59482	67777	62247	211904	115705	141580
8	43351	49078	44795	38948	62290	111894	378880	172568
9	47542	24445	28620	21732	26879	68779	137005	439028
10	63446	22642	12729	12234	11963	23085	66068	128985
11	12622	29824	11664	5196	6286	8840	19795	56017
12+	4882	8058	20039	12700	8826	10120	13937	26013
SSB total	317622	285597	275427	218478	242521	499264	831798	1081732

Spawning stock biomass (t) at Jan. 1

Year	1993	1994	1995	1996	1997	1998	1999	2000
------	------	------	------	------	------	------	------	------

Age								
-----	--	--	--	--	--	--	--	--

4	0	0	0	0	0	0	0	0
5	45854	63899	42430	15390	12501	10354	16815	24409
6	72316	124439	140304	109084	54758	41220	22881	44464
7	88663	103506	167519	173629	184034	96744	47133	30349
8	140161	93188	96626	145405	159890	183256	71814	39213
9	152894	120921	69586	62804	102023	105359	93776	44356
10	351441	118910	81516	37114	37294	57444	44279	47964
11	97396	251152	79325	40990	20262	19568	22593	21327
12+	60207	103534	228909	145054	97847	55302	25508	21397
SSB total	1008931	979550	906216	729469	668608	569246	344799	273479

Table 4.5

runid BUN28680 Wed Jan 17 09:27:23 2001

stocks cod.imm cod.mat

areas 0

Total stock biomass (t) at Jan. 1

Year 1983 1984

Age

3	118841	232972
4	155878	162811
5	173698	158154
6	143073	137173
7	191366	83165
8	264968	90544
9	51120	123195
10	10944	24688
11	5754	5372
12+	2654	4300
Total	1118295	1022373

Total stock biomass (t) at Jan. 1

Year 1985 1986 1987 1988 1989 1990 1991 1992

Age

3	286279	442478	128848	91947	81158	192244	532198	775993
4	406385	350962	467118	128673	132441	158031	268506	601613
5	248881	395824	337463	488209	170409	221447	199455	296584
6	172997	199544	293518	241444	500564	237440	250053	204256
7	116083	107956	123890	158543	184876	566428	251005	243092
8	53856	61641	56837	57833	98829	171179	557816	235173
9	48958	25960	30600	23897	32201	79475	156326	498845
10	64285	22771	12892	12465	12349	24159	68492	133684
11	12622	29824	11664	5196	6286	8840	19795	56017
12+	4882	8058	20039	12700	8826	10120	13937	26013
Total	1415228	1645017	1482869	1220907	1227937	1669361	2317582	3071270

Total stock biomass (t) at Jan. 1

Year 1993 1994 1995 1996 1997 1998 1999 2000

Age

3	661935	319805	162967	82930	152424	244343	123240	138439
4	656687	759546	326741	173224	121155	252648	359588	209976
5	522879	702858	735368	326429	204503	143092	259684	420289
6	240682	506329	559681	579247	296518	175565	103631	213043
7	156866	208946	360116	359517	410495	206142	97700	66951
8	182247	123003	137560	207915	213925	241906	97083	53506
9	174464	134669	77226	72940	114584	113892	101353	48685
10	368364	128078	85536	38649	38997	58938	45099	48772
11	97396	251152	79325	40990	20262	19568	22593	21327
12+	60207	103534	228909	145054	97847	55302	25508	21397
Total	3121725	3237922	2753429	2026894	1670711	1511395	1235478	1242386

Table 4.6

runid BUN28680 Wed Jan 17 09:27:23 2001

stocks cod.imm cod.mat

areas 0

Weight (kg) in catch (Observed)

Year	1983	1985	1986	1987	1988	1989	1990
------	------	------	------	------	------	------	------

Age

1	0.02	0.12	0.09	0.09	0.07	0.05	0.16
2	0.45	0.33	0.31	0.24	0.32	0.51	0.44
3	0.84	0.94	0.64	0.51	0.54	0.74	0.83
4	1.37	1.37	1.27	0.88	0.86	0.96	1.22
5	2.08	2.01	1.87	1.55	1.31	1.32	1.65
6	2.86	3.21	2.79	2.32	2.23	1.91	2.23
7	3.99	4.63	4.49	3.43	3.52	2.93	3.23
8	5.58	6.04	5.84	5.92	5.34	4.63	4.67
9	7.76	7.65	6.83	8.59	8.04	7.51	7.30
10	9.30	9.81	7.68	9.60	9.28	9.12	9.84
11	11.55	11.80	9.81	12.20	11.46	11.08	13.25
12+	16.46	14.08	11.17	13.61	15.42	14.95	14.21

Weight (kg) in catch (Observed)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	1997-1999
------	------	------	------	------	------	------	------	------	------	-----------

Age

1	0.12	0.06	0.14	0.04	0.11	0.08	0.10	0.12	0.06	0.09
2	0.48	0.54	0.49	0.41	0.40	0.31	0.33	0.35	0.33	0.34
3	1.05	1.17	0.80	0.84	0.81	0.82	0.71	0.69	0.64	0.68
4	1.45	1.57	1.50	1.30	1.25	1.13	1.06	1.06	1.03	1.05
5	2.16	2.22	2.16	2.00	1.79	1.63	1.54	1.61	1.49	1.55
6	2.89	3.11	2.80	2.86	2.57	2.45	2.22	2.28	2.26	2.25
7	3.74	4.26	4.16	3.21	3.78	3.83	3.41	3.28	3.18	3.29
8	4.71	5.18	5.55	5.27	4.94	5.81	5.29	4.85	4.30	4.82
9	6.07	6.13	6.48	6.86	6.14	6.85	7.32	6.89	6.01	6.74
10	8.80	7.77	7.19	7.60	8.02	8.10	7.83	9.44	6.80	8.03
11	11.80	10.11	7.99	8.05	8.82	9.51	8.62	10.63	10.83	10.03
12+	16.61	11.81	11.36	10.02	9.61	11.12	11.42	15.19	14.46	13.69

Table 4.7

runid BUN28680 Wed Jan 17 09:27:23 2001

stocks cod.imm cod.mat

areas 0

Weight (kg) in catch (Model)

Year	1983	1985	1986	1987	1988	1989	1990
------	------	------	------	------	------	------	------

Age

1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	0.69	0.85	0.63	0.51	0.63	0.83	1.17
4	1.27	1.40	1.18	0.92	0.95	1.16	1.57
5	1.87	1.99	1.80	1.49	1.35	1.48	2.08
6	3.02	2.99	2.45	2.21	2.01	2.01	2.57
7	4.53	4.01	3.59	3.01	2.90	2.88	3.38
8	6.34	5.54	4.79	4.51	3.88	4.01	4.63
9	8.99	7.99	6.46	6.20	5.70	5.20	6.16
10	10.73	9.84	8.82	8.51	7.70	7.13	7.61
11	12.55	11.97	9.85	11.84	10.18	8.71	9.62
12+	14.52	14.06	10.90	14.46	13.66	11.31	11.65

Weight (kg) in catch (Model)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	1997-1999
------	------	------	------	------	------	------	------	------	------	-----------

Age

1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-
3	1.20	1.10	0.76	0.63	0.66	0.63	0.67	0.72	0.57	0.65
4	1.74	1.56	1.41	1.11	1.03	1.08	1.16	1.17	1.05	1.13
5	2.39	2.23	1.92	1.81	1.59	1.52	1.71	1.71	1.61	1.68
6	3.10	3.11	2.66	2.41	2.51	2.31	2.40	2.51	2.37	2.43
7	3.77	4.01	3.70	3.26	3.32	3.49	3.53	3.57	3.52	3.54
8	4.82	4.82	4.74	4.55	4.36	4.56	5.08	5.22	4.97	5.09
9	6.30	6.06	5.66	5.80	5.97	5.87	6.50	7.34	7.02	6.95
10	7.71	7.73	7.05	6.82	7.41	7.85	8.05	9.10	9.01	8.72
11	8.72	9.20	9.04	8.55	8.71	9.36	10.11	10.71	10.22	10.34
12+	9.89	9.86	11.21	11.03	10.79	11.33	11.16	11.70	11.72	11.53

Table 4.8

runid BUN28680 Wed Jan 17 09:27:23 2001
 stocks cod.imm cod.mat
 areas 0

Weight (kg) in stock at Jan. 1										
Year	1983	1984	1985	1986	1987	1988	1989	1990	1991	
Age										
3	0.39	0.42	0.47	0.38	0.36	0.35	0.42	0.61	0.74	
4	0.98	0.73	0.98	0.78	0.58	0.54	0.69	1.09	1.17	
5	1.66	1.44	1.58	1.40	1.16	0.93	1.00	1.60	1.88	
6	2.79	2.22	2.66	2.06	1.94	1.60	1.55	2.07	2.54	
7	4.44	3.46	3.82	3.23	2.77	2.50	2.47	2.87	3.16	
8	6.05	5.53	5.47	4.44	4.25	3.49	3.70	4.19	4.19	
9	8.35	7.57	8.10	6.09	5.86	5.26	5.05	5.91	5.77	
10	9.95	10.54	10.47	8.59	8.06	7.13	7.41	7.77	7.71	
11	11.51	12.67	13.96	10.78	11.46	9.68	9.88	11.04	9.79	
12+	13.27	15.47	17.13	14.26	15.19	15.64	17.10	17.54	15.25	

Weight (kg) in stock at Jan. 1										
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	1997-1999
Age										
3	0.76	0.42	0.30	0.26	0.23	0.26	0.29	0.24	0.24	0.26
4	1.18	0.93	0.77	0.64	0.61	0.63	0.69	0.64	0.57	0.65
5	1.83	1.47	1.50	1.24	1.10	1.19	1.24	1.21	1.15	1.21
6	2.82	2.21	2.16	2.08	1.85	1.86	2.04	1.91	1.89	1.94
7	3.74	3.35	2.99	2.83	2.93	2.92	3.09	2.94	2.79	2.98
8	4.56	4.42	4.27	3.82	3.94	4.40	4.74	4.25	4.16	4.47
9	5.84	5.39	5.42	5.43	5.17	5.80	6.89	6.16	5.91	6.28
10	7.71	6.88	6.37	6.90	7.14	7.51	8.86	8.48	8.31	8.28
11	10.00	9.13	8.02	8.33	8.92	10.33	11.30	10.56	11.15	10.73
12+	13.81	12.78	11.17	11.47	12.65	16.02	19.11	16.37	15.53	17.17

Table 4.9

runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0

Proportion mature at age										
Year	1983	1984	1985	1986	1987	1988	1989	1990	1991	
Age										
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
4	0.079	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
5	0.097	0.133	0.099	0.094	0.072	0.037	0.033	0.092	0.127	
6	0.367	0.228	0.334	0.262	0.251	0.173	0.117	0.187	0.300	
7	0.640	0.539	0.545	0.574	0.480	0.427	0.337	0.374	0.461	
8	0.705	0.844	0.805	0.796	0.788	0.673	0.630	0.654	0.679	
9	0.781	0.919	0.971	0.942	0.935	0.909	0.835	0.865	0.876	
10	1.000	0.966	0.987	0.994	0.987	0.981	0.969	0.956	0.965	
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
12+	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	

Proportion mature at age										
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	1998-2000
Age										
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
5	0.147	0.088	0.091	0.058	0.047	0.061	0.072	0.065	0.058	0.0650
6	0.362	0.300	0.246	0.251	0.188	0.185	0.235	0.221	0.209	0.2217
7	0.582	0.565	0.495	0.465	0.483	0.448	0.469	0.482	0.453	0.4680
8	0.734	0.769	0.758	0.702	0.699	0.747	0.758	0.740	0.733	0.7437
9	0.880	0.876	0.898	0.901	0.861	0.890	0.925	0.925	0.911	0.9203
10	0.965	0.954	0.928	0.953	0.960	0.956	0.975	0.982	0.983	0.9800
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.0000
12+	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.0000

Table 4.10

runid BUN28680 Wed Jan 17 09:27:23 2001

stocks cod.imm cod.mat

areas 0

fleets danish_seineD.cod gillnetD.cod handlineD.cod longlineD.cod
nortrawlD.cod rustrawltotalD.cod

Model catch in numbers (thousands) at age

Year	1983	1985	1986	1987	1988	1989	1990	1991
Age								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	7089	21580	35922	9556	7558	5572	7112	22361
4	18019	47442	66674	93940	20105	15780	8154	14227
5	23133	31120	77647	80451	102862	22908	11329	10177
6	18280	20121	34319	58645	48499	65424	11137	11126
7	19867	11522	14295	19710	25591	20443	22313	9753
8	20583	4005	6302	6347	7361	8540	5090	17514
9	2792	2424	1944	2514	2120	2164	1725	3663
10	497	2346	1177	763	814	570	398	1191
11	220	323	1194	476	245	212	100	266
12+	86	97	235	605	354	159	69	114
Total	110566	140980	239708	273005	215509	141771	67427	90391

Model catch in numbers (thousands) at age

Year	1992	1993	1994	1995	1996	1997	1998	1999
Age								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	31435	24457	13327	9631	5726	16735	31567	10450
4	32806	51293	82091	46539	30912	27940	69217	78213
5	15088	41422	84879	135763	71109	51208	38781	62462
6	8783	16344	54186	89563	109461	63017	37067	20675
7	8702	8511	18347	48828	50584	64947	32081	14668
8	7185	7988	8335	14878	23184	23789	25766	10734
9	12154	6413	7338	6138	6322	9785	8380	7829
10	2449	10648	5939	5328	2430	2550	3347	2495
11	772	2083	9154	4039	2028	942	860	987
12+	249	886	2625	8159	4871	2809	1386	692
Total	119622	170045	286221	368865	306626	263720	248451	209206

Table 4.11

runid BUN28680 Wed Jan 17 09:27:23 2001

stocks cod.imm cod.mat

areas 0

fleets danish_seineD.cod gillnetD.cod handlineD.cod longlineD.cod

nortrawlD.cod rustrawltotalD.cod

Observed catch in numbers (thousands) at age

Year	1983	1985	1986	1987	1988	1989	1990	1991
Age								
1	382	92	33	14	3	2	5	16
2	475	1504	816	310	171	232	111	369
3	5275	19827	24601	10451	9320	4905	1318	3498
4	14129	41156	59095	117702	19556	15829	5815	8518
5	18164	24947	71522	84258	117466	28910	9871	12313
6	14398	16756	23485	57247	48956	66518	13789	15180
7	12598	10562	10443	13079	19909	24998	23675	14196
8	13092	3509	3796	3576	3153	5194	5160	18101
9	2148	1437	890	872	1163	795	607	2706
10	580	713	696	450	384	275	127	270
11	227	132	517	184	105	41	49	36
12+	91	97	206	308	128	40	20	14
Total	81559	120732	196100	288451	220314	147739	60547	75217

Observed catch in numbers (thousands) at age

Year	1992	1993	1994	1995	1996	1997	1998	1999
Age								
1	91	9	22	8	175	78	92	21
2	771	306	167	208	728	664	1453	296
3	14281	7684	5560	4744	7029	10454	28163	8086
4	22808	37104	49637	35103	25578	32825	78276	72596
5	18690	54335	79313	95626	70977	63737	42661	81445
6	17119	28253	50250	79442	87255	75833	35607	27626
7	12909	11530	28783	28300	46093	60404	29470	13875
8	9545	7452	7686	6796	8735	22662	23807	14380
9	12829	5190	4522	2499	1797	3198	6147	7971
10	1766	9814	2497	1441	817	817	886	1815
11	194	1302	5466	811	362	355	172	203
12+	49	299	853	1871	844	413	136	91
Total	111052	163278	234756	256849	250390	271440	246870	228405

Table 4.12

runid BUN28680 Wed Jan 17 09:27:23 2001

stocks cod.imm cod.mat

areas 0

fleets danish_seineD.cod gillnetD.cod handlineD.cod longlineD.cod
nortrawlD.cod rustrawltotalD.cod

Model catch in biomass (t) at age

Year	1983	1985	1986	1987	1988	1989	1990	1991
Age								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	4857	18275	22648	4907	4782	4621	8294	26743
4	22928	66428	78556	86499	19001	18274	12825	24783
5	43170	61817	139442	119826	139322	33902	23585	24287
6	55117	60076	84041	129586	97576	131264	28675	34524
7	89980	46249	51262	59374	74089	58845	75336	36739
8	130428	22189	30204	28645	28546	34270	23558	84343
9	25096	19364	12568	15584	12089	11262	10622	23067
10	5335	23086	10381	6488	6264	4066	3029	9192
11	2761	3872	11759	5634	2493	1845	961	2317
12+	1242	1362	2560	8754	4837	1796	802	1128
Total	380912	322719	443420	465294	388998	300143	187687	267121

Model catch in biomass (t) at age

Year	1992	1993	1994	1995	1996	1997	1998	1999
Age								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	34602	18530	8449	6374	3613	11287	22580	5911
4	51030	72401	91498	48108	33480	32341	80841	82460
5	33601	79435	153333	215804	108304	87518	66272	100465
6	27340	43458	130450	224529	252533	151322	93005	49000
7	34928	31528	59776	161971	176555	229379	114370	51622
8	34640	37856	37919	64833	105612	120884	134519	53399
9	73640	36264	42525	36640	37092	63583	61479	54993
10	18924	75020	40533	39468	19066	20518	30474	22485
11	7103	18841	78257	35194	18979	9516	9208	10084
12+	2453	9937	28951	88024	55212	31352	16218	8118
Total	318258	423270	671690	920945	810447	757700	628964	438537

Table 4.13

runid BUN28680 Wed Jan 17 09:27:23 2001

stocks cod.imm cod.mat

areas 0

fleets danish_seineD.cod gillnetD.cod handlineD.cod longlineD.cod
nortrawlD.cod rustrawltotalD.cod

Observed catch in biomass (t) at age

Year	1983	1985	1986	1987	1988	1989	1990	1991
Age								
1	8	11	3	1	0	0	1	2
2	214	498	250	75	54	118	49	178
3	4457	18541	15729	5303	5068	3654	1094	3663
4	19398	56430	74809	103615	16787	15245	7117	12312
5	37870	50216	134094	130619	154429	38035	16335	26586
6	41142	53841	65500	132881	109296	127317	30725	43831
7	50245	48881	46853	44903	70054	73174	76473	53104
8	72992	21189	22168	21173	16824	24028	24108	85331
9	16675	10999	6080	7493	9352	5968	4431	16431
10	5395	6991	5346	4320	3565	2507	1249	2377
11	2621	1557	5071	2245	1203	454	649	425
12+	1498	1366	2301	4193	1974	598	284	232
Total	252514	270521	378203	456821	388606	291097	162514	244473

Observed catch in biomass (t) at age

Year	1992	1993	1994	1995	1996	1997	1998	1999
Age								
1	5	1	1	1	14	8	11	1
2	420	151	68	83	229	219	508	99
3	16698	6169	4687	3828	5735	7437	19474	5211
4	35829	55751	64423	43838	28884	34792	82714	74652
5	41519	117097	158367	171270	115499	98445	68716	121180
6	53169	79208	143844	204440	213474	168154	81289	62357
7	54966	47910	92517	106962	176528	205811	96598	44146
8	49414	41384	40470	33573	50792	119901	115574	61880
9	78612	33656	31016	15353	12315	23400	42378	47875
10	13728	70541	18989	11563	6620	6401	8364	12342
11	1961	10407	44007	7156	3441	3062	1828	2199
12+	579	3397	8550	17989	9383	4717	2065	1316
Total	346898	465673	606939	616056	622914	672345	519519	433258

Figure 4.1. Initial run; Modelled (full line) and observed (dashed line) survey estimate by length for the Russian bottom trawl survey.

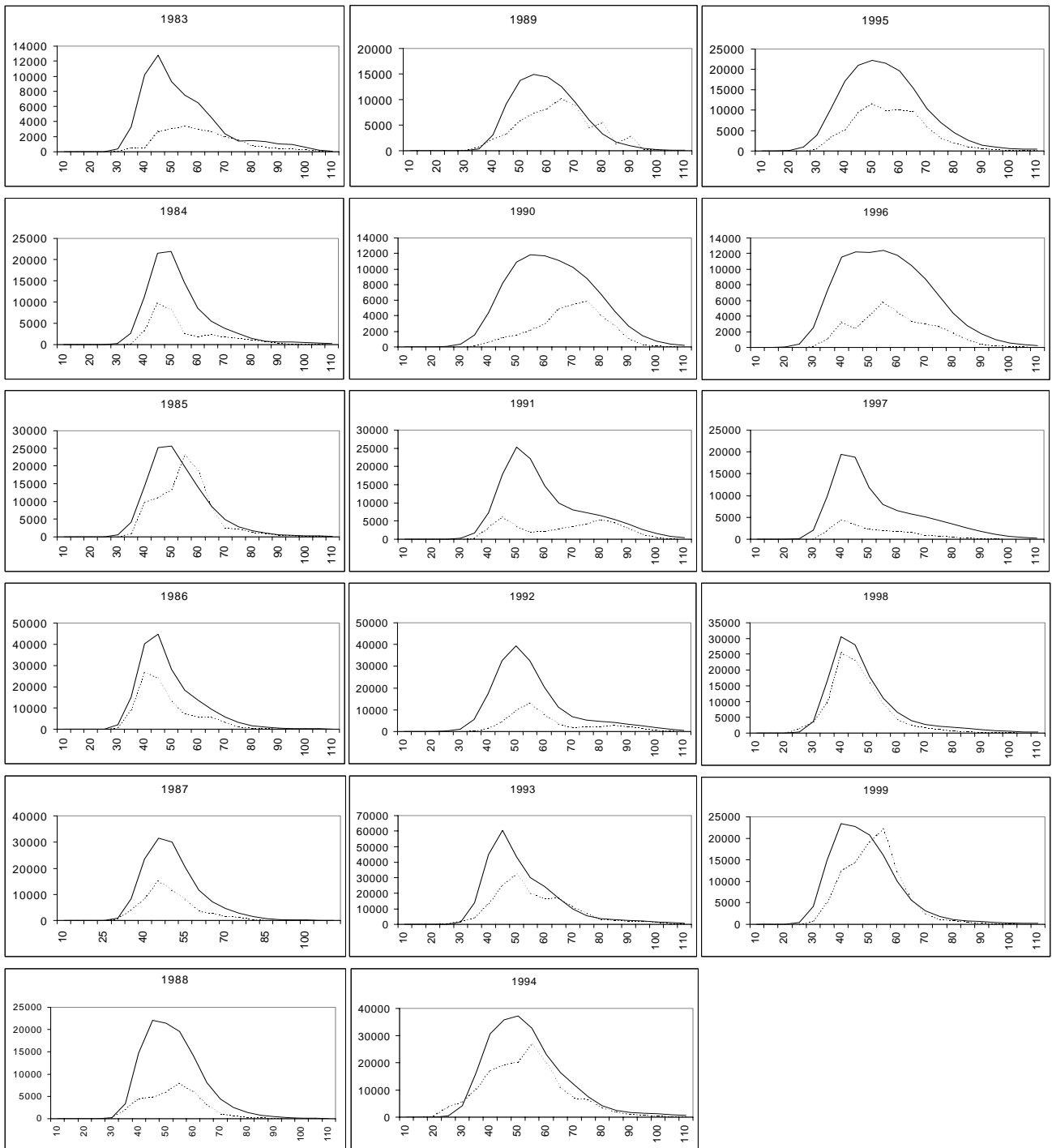


Figure 4.2 Initial run; Modelled (full line) and observed (dashed line) survey estimate by length for the Norwegian bottom trawl winter survey.

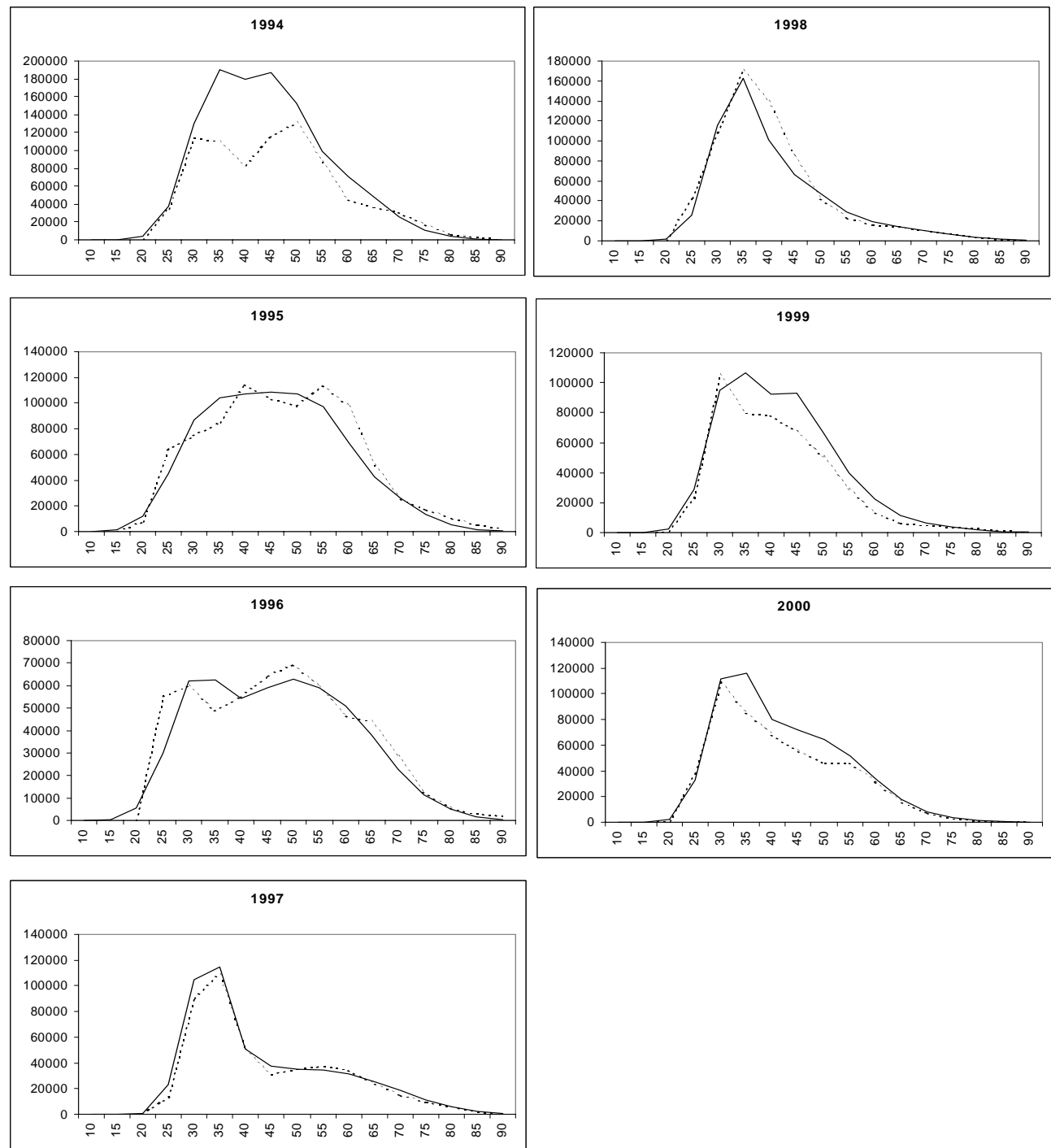


Figure 4.3 Modelled catch when starting values were changed for 15 parameters (diamonds) compared to initial run (pluses) and observed catch (squares).

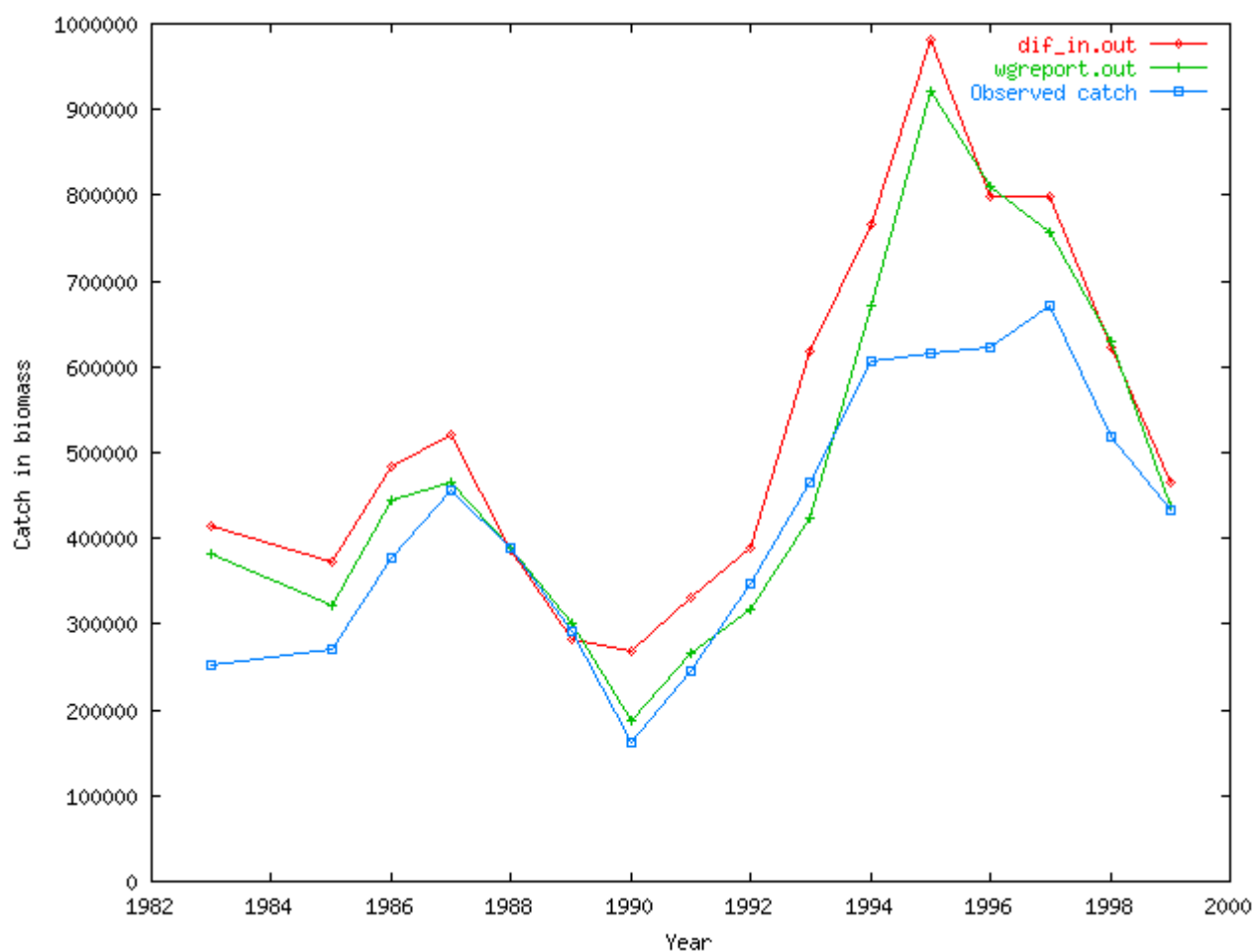


Figure 4.4 Modelled average fishing mortality for ages 5-10 when starting values were changed for 15 parameters (diamonds) compared to initial run (pluses).

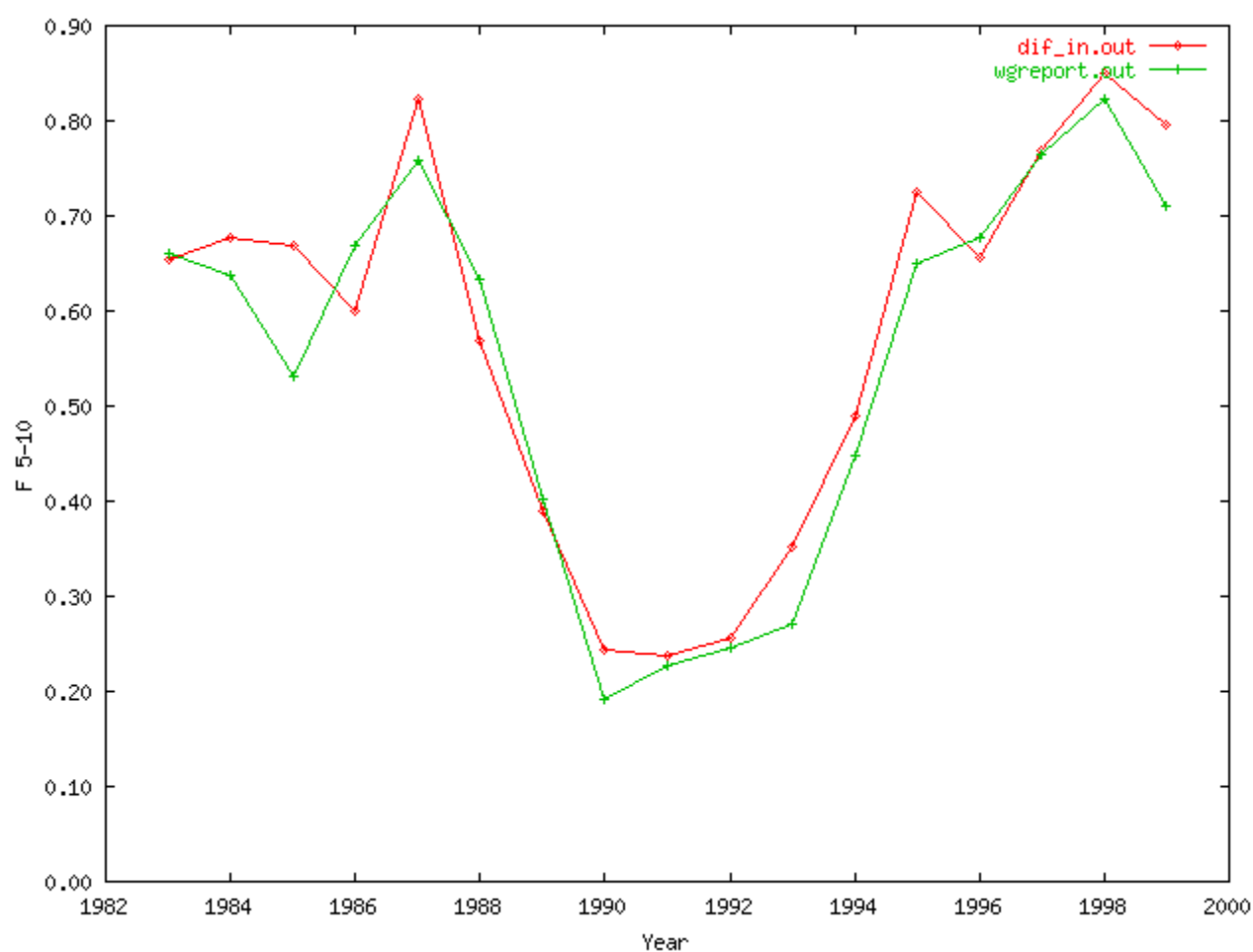


Figure 4.5 Modelled recruitment when starting values were changed for 15 parameters (diamonds) compared to initial run (pluses)

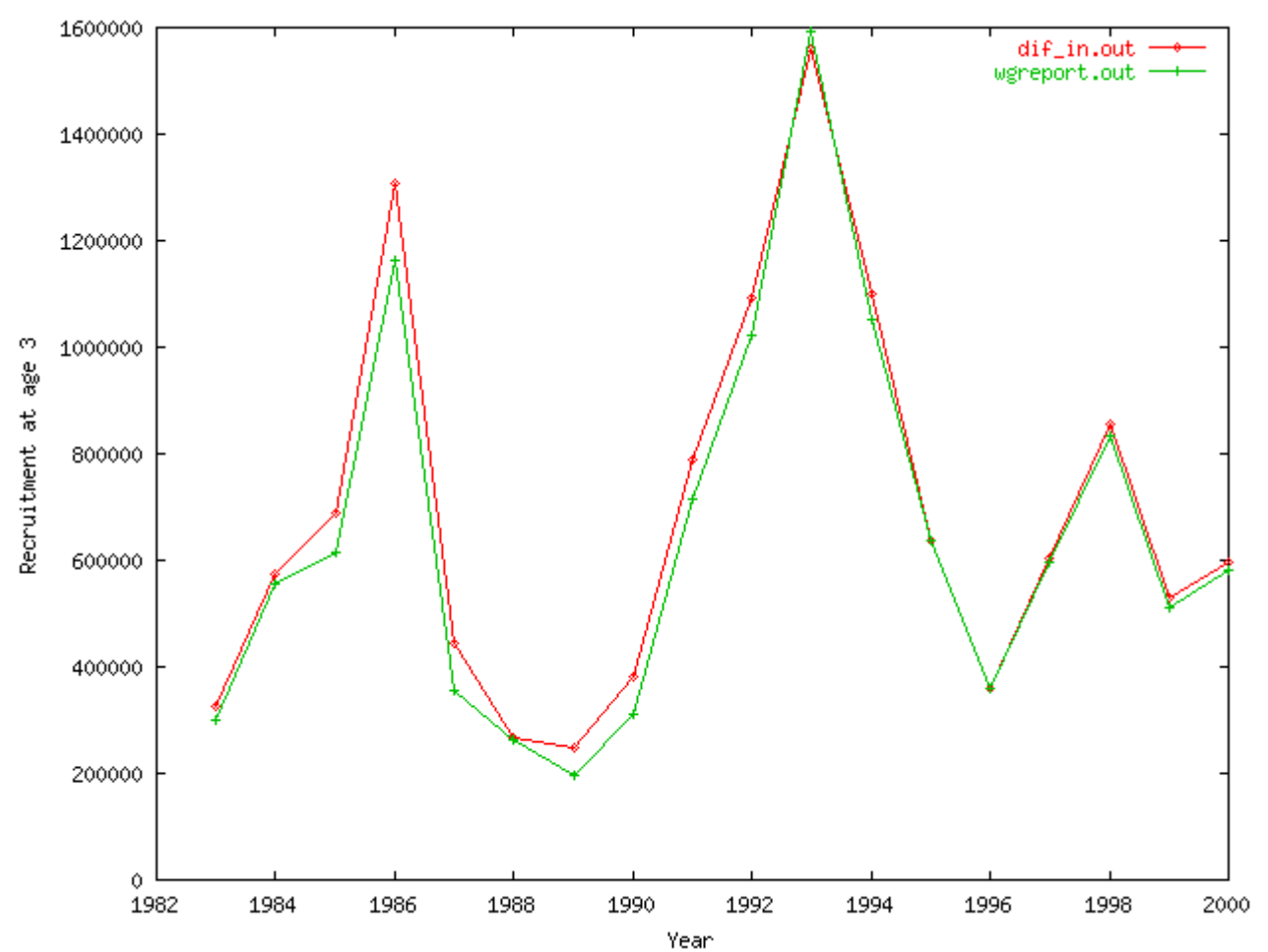


Figure 4.6. Modelled spawning stock biomass when starting values were changed for 15 parameters (diamonds) compared to initial run (pluses).

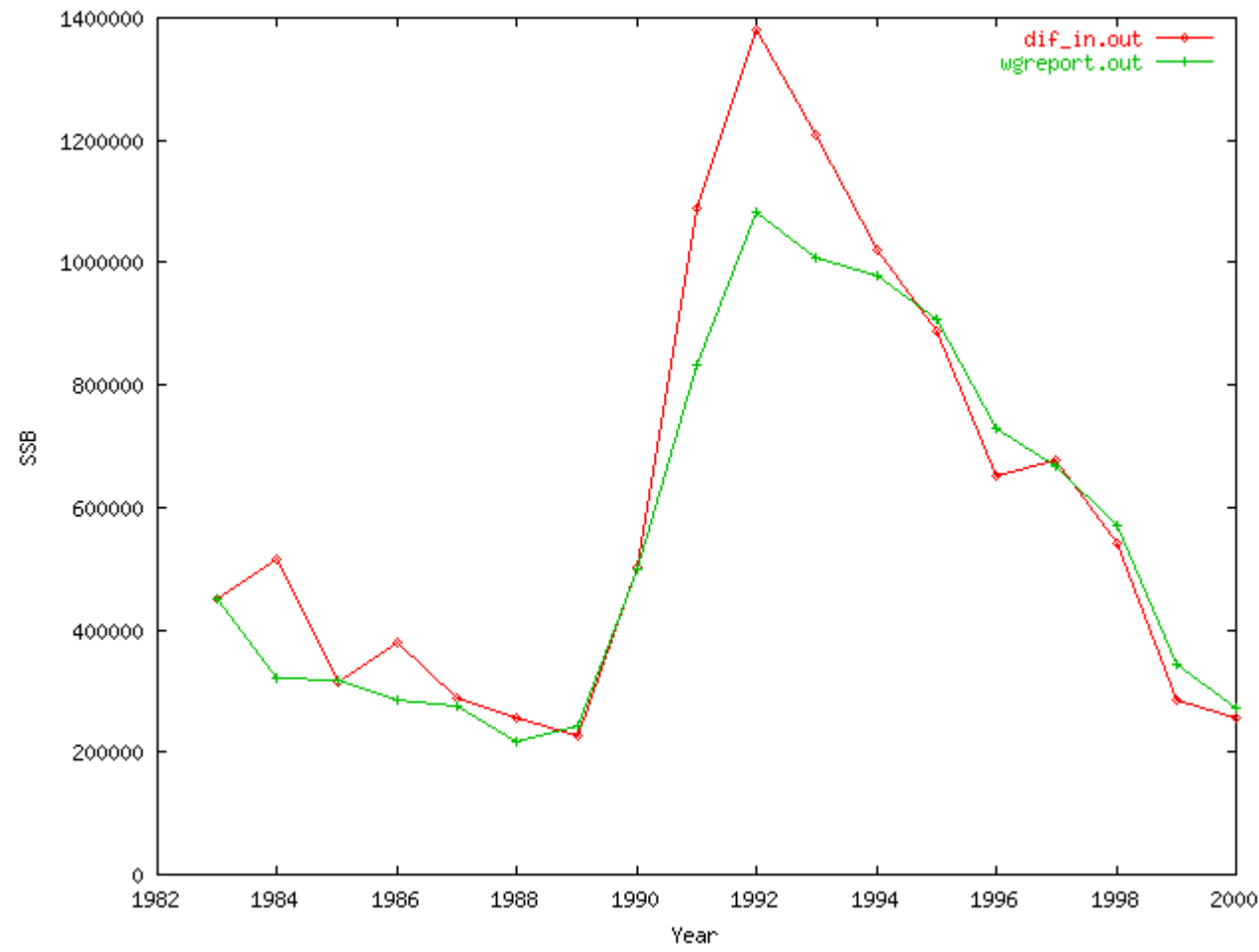


Figure 4.7 Modelled catch when yearly growth rates were fixed (diamonds) compared to initial run (pluses) and observed catch (squares).

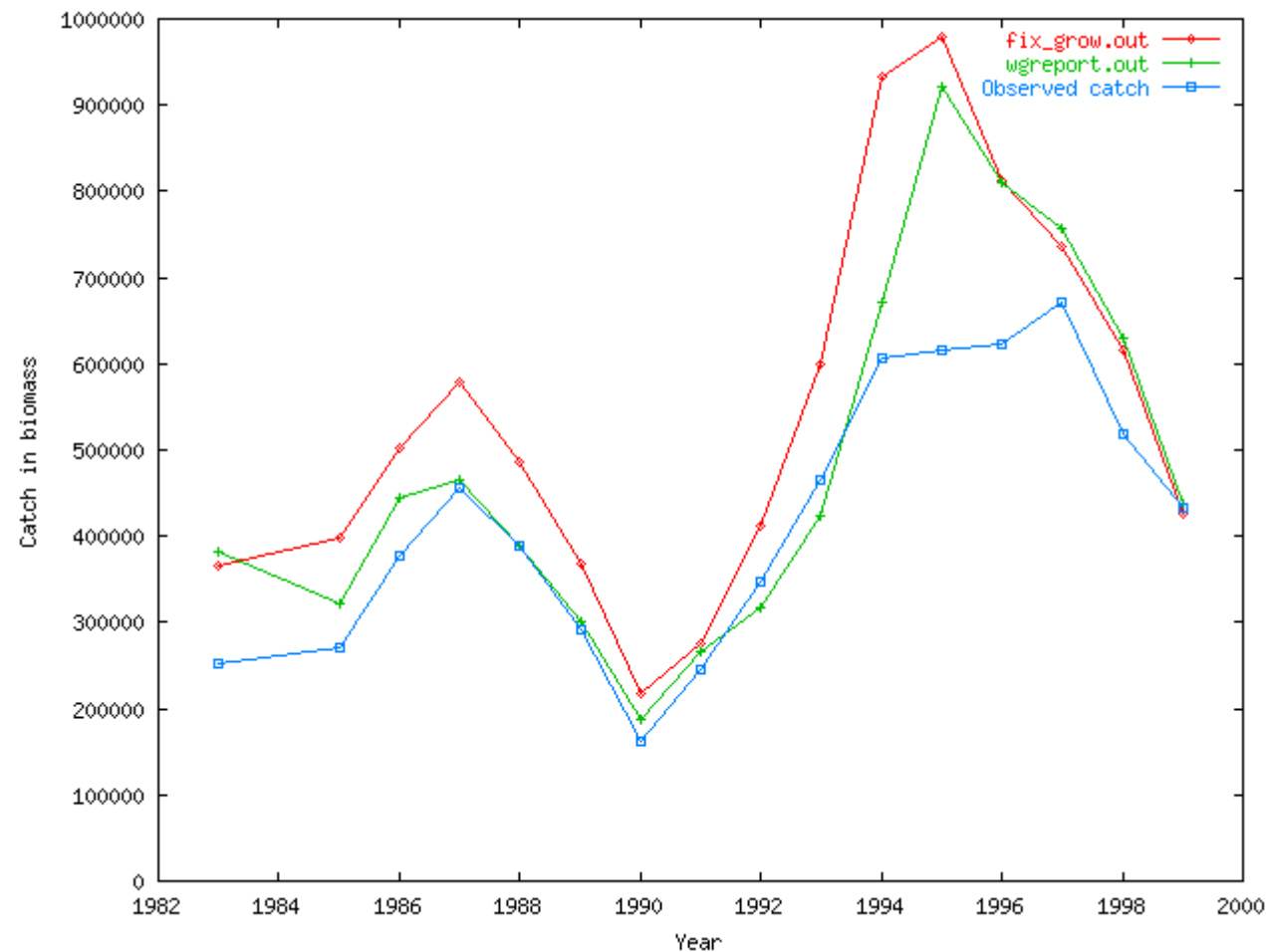


Figure 4.8 Modelled average fishing mortality for ages 5-10 when yearly growth rates were fixed (diamonds) compared to initial run (pluses).

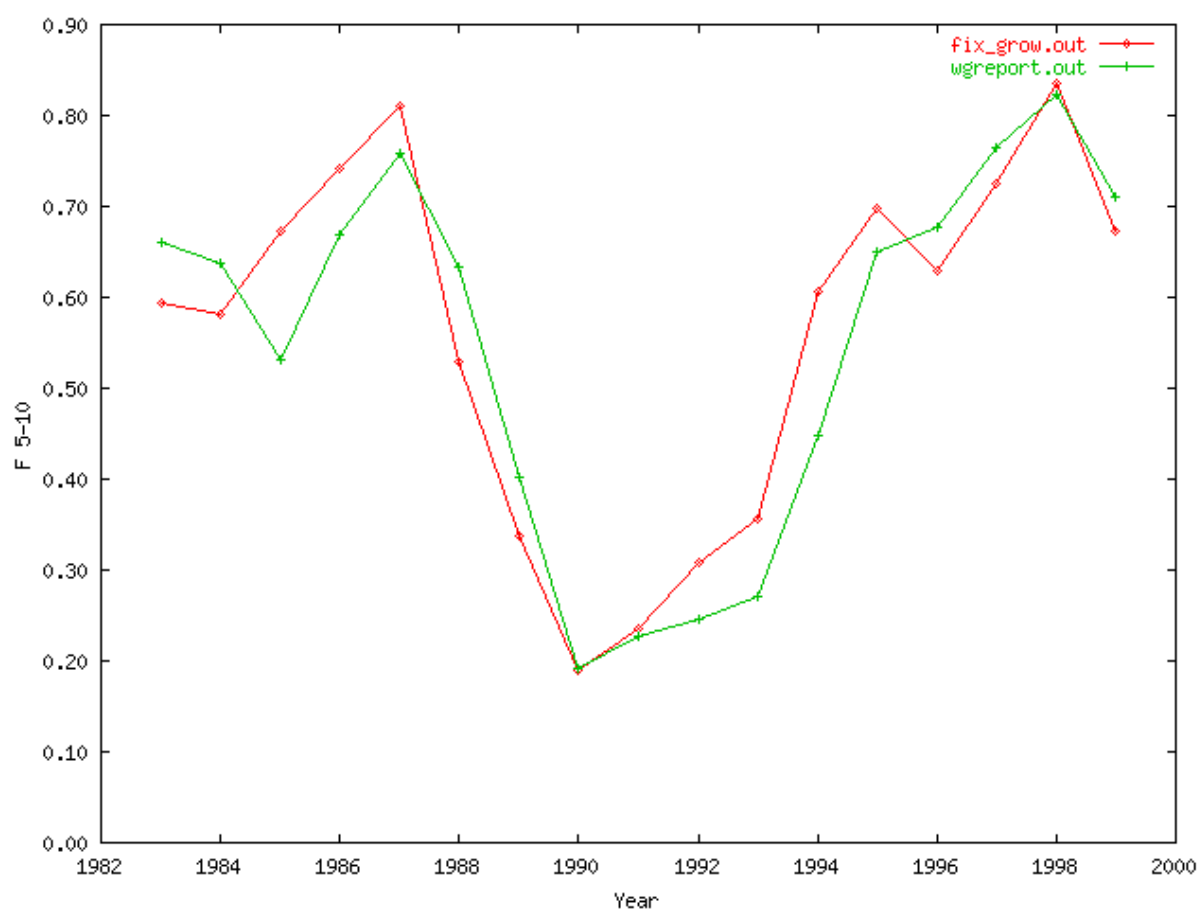


Figure 4.9 Modelled recruitment when yearly growth rates were fixed (diamonds) compared to initial run (pluses).

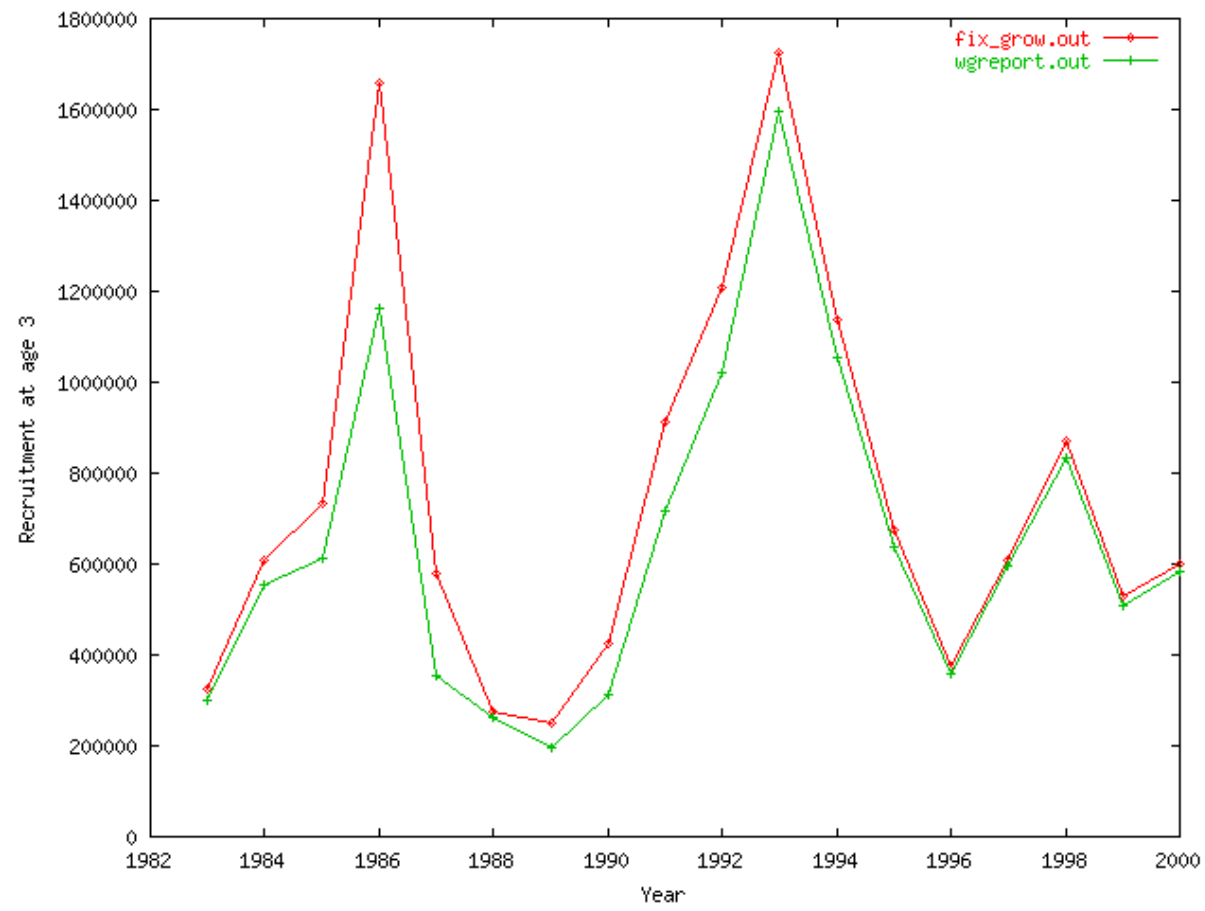


Figure 4.10 Modelled spawning stock biomass when yearly growth rates were fixed (diamonds) compared to initial run (pluses).

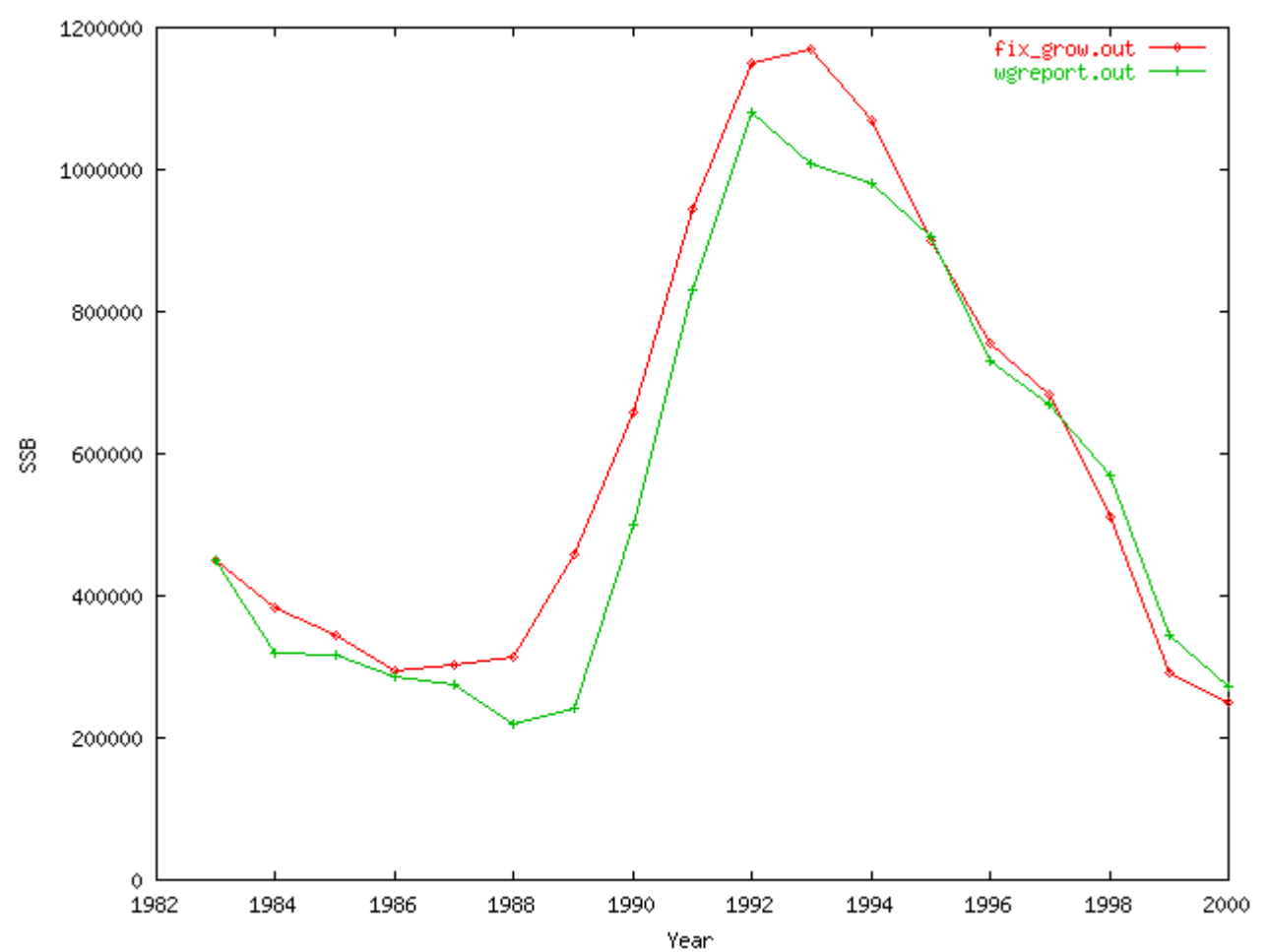


Figure 4.11 Modelled spawning stock biomass when optimising alpha in the consumption equation (pluses) compared to initial run (diamonds) and the assessment at AFWG, August 2000 (squares).

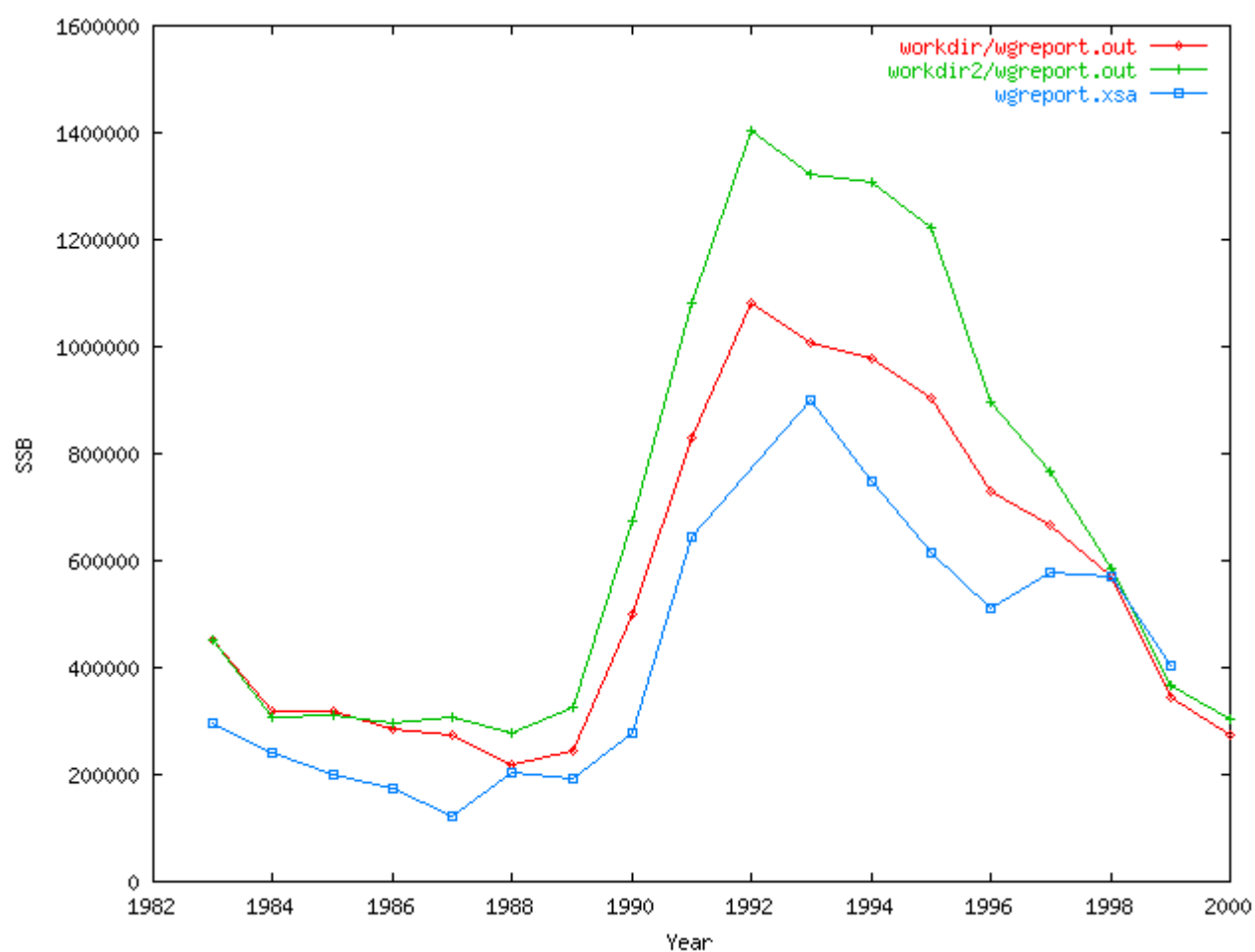


Figure 4.12 Modelled catch when optimising alpha in the consumption equation (pluses) compared to initial run (diamonds) and the observed catch (x-es).

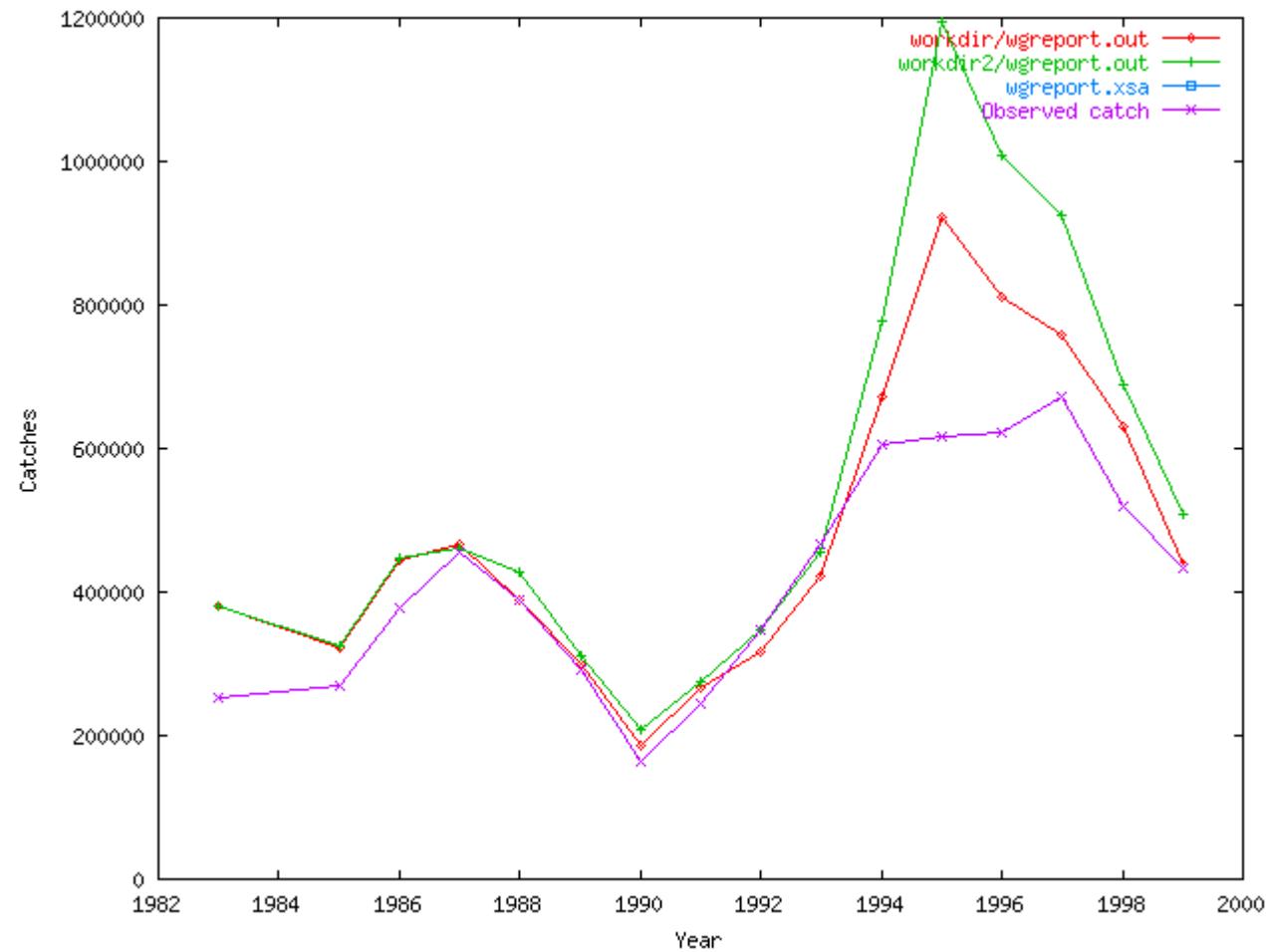
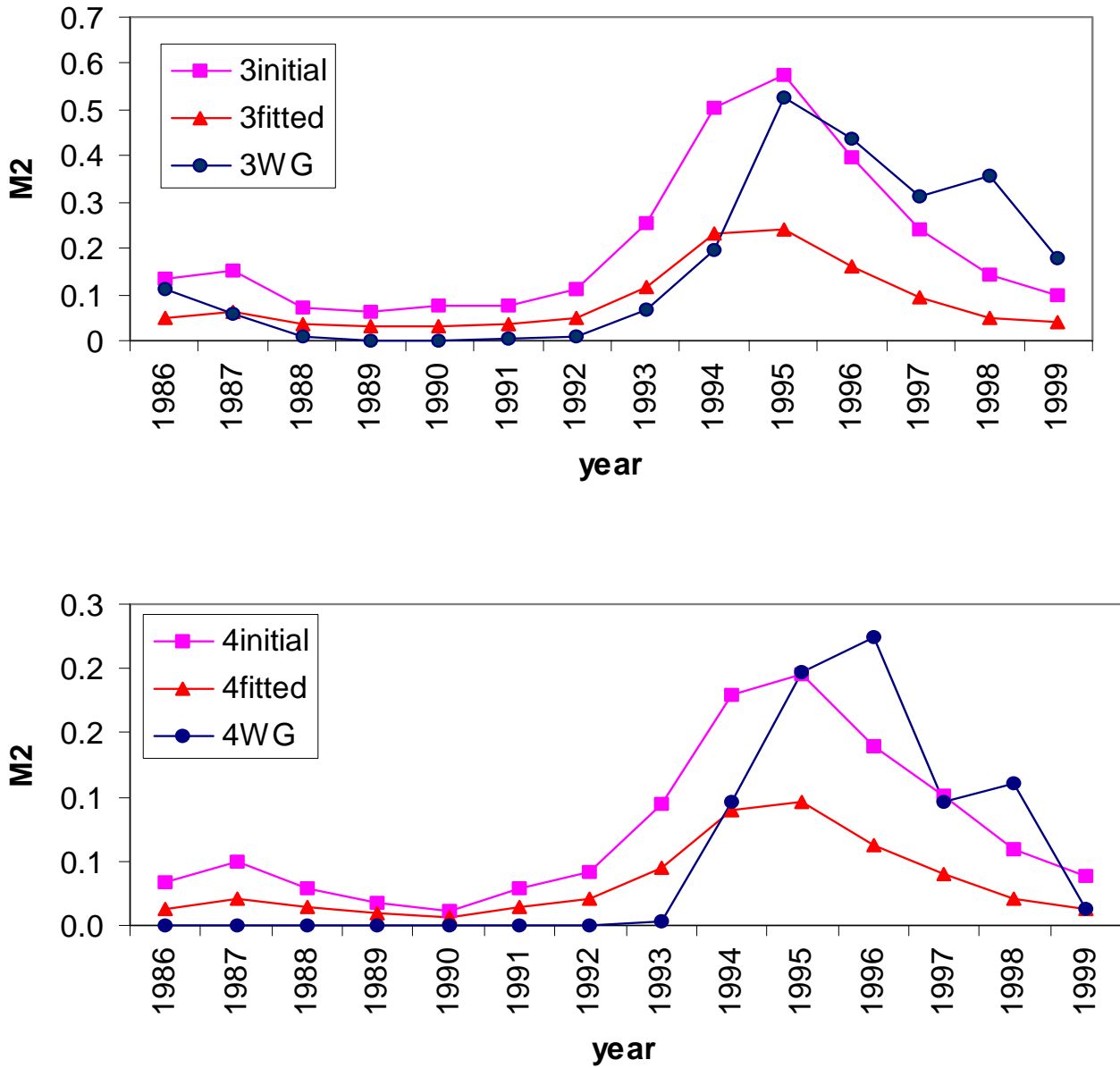


Figure 4.13 Estimated predation mortality (M2) for age 3 (upper panel) and age 4 (lower panel) in the initial run (“initial”) and in the run where alpha in the consumption equation was optimised (“fitted”) and in the assessment at AFWG, August 2000 (“WG”).



APPENDIX 1

;This optfile was generated from runid BUN28680 Tue Jan 16 16:51:45 2001
switches value optimize

;Growth parameter for each year

growth.1983	7.500481	1	;	[12.4448]
growth.1984	12.7195	1	;	[12.7195]
growth.1985	8.36056	1	;	[8.36056]
growth.1986	8.41845	1	;	[8.41845]
growth.1987	5.659269	1	;	[5.14479]
growth.1988	8.21156	1	;	[8.21156]
growth.1989	13.50927	1	;	[15.0103]
growth.1990	10.107798	1	;	[9.44654]
growth.1991	8.956818	1	;	[9.95202]
growth.1992	4.424553	1	;	[4.91617]
growth.1993	7.859772	1	;	[8.73308]
growth.1994	8.05806	1	;	[8.9534]
growth.1995	8.579318	1	;	[7.79938]
growth.1996	10.9841	1	;	[10.9841]
growth.1997	12.482176	1	;	[11.1448]
growth.1998	10.457571	1	;	[11.2447]
growth.1999	10.187144	1	;	[11.5763]
growth.2000	9.6	1	;	[9.6]

;Growth distribution parameters

growth.k0	-0.072783	0	;		Growth distribution param. k0
growth.k1	0.5947425	1	;	[0.540675] Growth distribution param. k1
growth.exponent	0	0			
growth.ratio	0.88	1	;	[0.8] Ratio of Mature/immature growth

;Cannibalism parameters

cann_beta	0.00103295	0	;		Cannibalism parameter beta
cann_gamma	0.0001	0	;		Cannibalism parameter gamma
cann_delta	0.309428	0	;		Cannibalism parameter delta
cann_alpha	7e-06	0	;		Cannibalism parameter alpha

;Quarterly natural residual mortality of immature fish (in 3 length intervals)

imm.mort1	0.05	0	;		Quart. imm mortality length 1
imm.mort2	0.05	0	;		Quart. imm mortality length 2
imm.mort3	0.05	0	;		Quart. imm mortality length 3

;Number of immature fish in startyear of age x (10^7)

imm.n_age3	30.125851	1	;	[24.3579]
imm.n_age4	14.997377	1	;	[13.8161]
imm.n_age5	9.6564423	1	;	[6.61219]
imm.n_age6	3.6446964	1	;	[4.53659]
imm.n_age7	1.7841371	1	;	[2.80878]
imm.n_age8	1.6088661	1	;	[2.62073]
imm.n_age9	0.1727837	1	;	[0.364292]
imm.n_age10	0	0			

;Mean length (cm) of immature fish in startyear at age x

imm.l_age3	34.8	0			
imm.l_age4	45.9	0			
imm.l_age5	54.5	0			
imm.l_age6	62.7	0			
imm.l_age7	73.1	0			
imm.l_age8	78.6	0			
imm.l_age9	85	0			
imm.l_age10	90	0			

Continued.....

;Standard Deviation of mean length of immature fish in startyear at age x

imm.d_age3	4.2	0
imm.d_age4	4.7	0
imm.d_age5	4.3	0
imm.d_age6	5.2	0
imm.d_age7	4.2	0
imm.d_age8	6.8	0
imm.d_age9	13.7	0
imm.d_age10	13.5	0

;Maturation parameters

maturation.slope	0.03	0 ;	Maturation, slope
maturation.l50	78.44	0 ;	Maturation, L50

;Number of minimum-age fish at start of year x (10^7)

n_minage.1984	55.429371	1 ;[53.4259]
n_minage.1985	61.420098	1 ;[60.818]
n_minage.1986	116.44502	1 ;[123.105]
n_minage.1987	35.517037	1 ;[46.4093]
n_minage.1988	26.2487	1 ;[35.5]
n_minage.1989	19.527306	1 ;[22.4426]
n_minage.1990	31.26683	1 ;[37.6845]
n_minage.1991	71.476955	1 ;[54.2067]
n_minage.1992	102.05567	1 ;[89.8773]
n_minage.1993	159.40982	1 ;[115.867]
n_minage.1994	105.36738	1 ;[106.185]
n_minage.1995	63.747093	1 ;[61.5676]
n_minage.1996	35.9254	1 ;[41.7543]
n_minage.1997	59.449775	1 ;[69.3211]
n_minage.1998	83.341917	1 ;[84.7229]
n_minage.1999	51.036035	1 ;[48.2519]
n_minage.2000	58.137946	1 ;[57.9294]

;Mean length of minimum-age fish at start of year x

l_minage.1984	34.4754	1 ;[35.8]
l_minage.1985	37.1566	1 ;[40.3]
l_minage.1986	33.88056	1 ;[34.4]
l_minage.1987	33.43134	1 ;[31.8]
l_minage.1988	33.73326	1 ;[29.7]
l_minage.1989	34.4224	1 ;[34.7]
l_minage.1990	38.46228	1 ;[39.4]
l_minage.1991	40.7264	1 ;[41.6]
l_minage.1992	41.88646	1 ;[41.3]
l_minage.1993	34.9307	1 ;[35.9]
l_minage.1994	31.293	1 ;[30.5]
l_minage.1995	29.02692	1 ;[29.9]
l_minage.1996	28.31356	1 ;[28.1]
l_minage.1997	29.9292	1 ;[28]
l_minage.1998	31.09358	1 ;[28.7]
l_minage.1999	29.348	1 ;[29]
l_minage.2000	29.23382	1 ;[28.7]

Continued.....

;Standard deviation of mean length of minimum-age fish at start of year x

d_minage.1984	4.3	0
d_minage.1985	5.1	0
d_minage.1986	4.4	0
d_minage.1987	3.5	0
d_minage.1988	3.1	0
d_minage.1989	3.4	0
d_minage.1990	6.8	0
d_minage.1991	5.8	0
d_minage.1992	6.5	0
d_minage.1993	4.4	0
d_minage.1994	5	0
d_minage.1995	5.9	0
d_minage.1996	5	0
d_minage.1997	3.9	0
d_minage.1998	4.4	0
d_minage.1999	4.2	0
d_minage.2000	4.1	0

;Quarterly natural residual mortality of mature fish (in 3 length intervals)

mat.mort1	0.05	0 ;	Quart. mat mortality length 1
mat.mort2	0.05	0 ;	Quart. mat mortality length 2
mat.mort3	0.05	0 ;	Quart. mat mortality length 3

;Number of mature fish in startyear of age x (10⁷)

mat.n_age4	0.94	0
mat.n_age5	0.81	0
mat.n_age6	1.49	0
mat.n_age7	2.53	0
mat.n_age8	2.77	0
mat.n_age9	0.44	0
mat.n_age10	0.11	0
mat.n_age11	0.05	0
mat.n_age12	0.02	0

;Mean length (cm) of mature fish in startyear at age x

mat.l_age4	51	0
mat.l_age5	59.6	0
mat.l_age6	71.1	0
mat.l_age7	79	0
mat.l_age8	88.2	0
mat.l_age9	97.3	0
mat.l_age10	100	0
mat.l_age11	105	0
mat.l_age12	110	0

;Standard Deviation of mean length of mature fish in startyear at age x

mat.d_age4	1.06835	0
mat.d_age5	1.05602	0
mat.d_age6	1.01149	0
mat.d_age7	1.82767	0
mat.d_age8	2.56627	0
mat.d_age9	4.00303	0
mat.d_age10	7.15294	0
mat.d_age11	7.33135	0
mat.d_age12	9.03202	0

Continued.....

```

;fleet names
;11 dan - Danish seine
;12 gil - Gillnet
;13 hnd - Handline
;14 lng - Longline
;15 nor - Norwegian trawl
;16 rus - Russian trawl
;17 trd - Third countries
;18 ovr - Overfishing
;Catches, selection parameters
;05 slope
;06 l50

;Danish seine
dan.slope      0.067852885  1 ;[0.0607076 ] Slope of selection curve
dan.l50        45.961647   1 ;[48.9944   ] L50 of selection curve
dan.f1983      0.054864692  1 ;[0.0587794 ] Partial F
dan.f1985      0.023539584  1 ;[0.0219238 ]
dan.f1986      0.023756406  1 ;[0.0221278 ]
dan.f1987      0.0087118268 1 ;[0.0104634 ]
dan.f1988      0.013480782  1 ;[0.0181976 ]
dan.f1989      0.013860523  1 ;[0.0176029 ]
dan.f1990      0.0063175232  1 ;[0.00826144]
dan.f1991      0.0058644727  1 ;[0.00635922]
dan.f1992      0.0044601598  1 ;[0.00595641]
dan.f1993      0.007392659  1 ;[0.0086952 ]
dan.f1994      0.010762389  1 ;[0.0133794 ]
dan.f1995      0.024649586  1 ;[0.0230026 ]
dan.f1996      0.060172148  1 ;[0.0550674 ]
dan.f1997      0.037391022  1 ;[0.0704295 ]
dan.f1998      0.049328359  1 ;[0.0732092 ]
dan.f1999      0.039700965  1 ;[0.0466631 ]

;Gillnet
gil.p0         0           0 ; Parameters for bell-shaped selection curve
gil.p1         0.20138     1 ;[0.2         ]
gil.p2         1           0
gil.p3         0.052317    1 ;[0.03         ]
gil.p4         0.18603     1 ;[0.1         ]
gil.f1983      0.2916      1 ;[0.5         ] Partial F
gil.f1985      0.25587     1 ;[0.45         ]
gil.f1986      0.17688     1 ;[0.3         ]
gil.f1987      0.11294     1 ;[0.2         ]
gil.f1988      0.15171     1 ;[0.3         ]
gil.f1989      0.13908     1 ;[0.3         ]
gil.f1990      0.028421045  1 ;[0.0946737 ]
gil.f1991      0.0326      1 ;[0.1         ]
gil.f1992      0.037814    1 ;[0.074        ]
gil.f1993      0.055104    1 ;[0.12         ]
gil.f1994      0.077779    1 ;[0.13         ]
gil.f1995      0.19629     1 ;[0.27         ]
gil.f1996      0.17421     1 ;[0.3         ]
gil.f1997      0.19311     1 ;[0.3         ]
gil.f1998      0.13992     1 ;[0.2         ]
gil.f1999      0.14368     1 ;[0.2         ]

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Continued.....

```
;Handline
hnd.slope      0.038828744  1 ;[0.0405734 ] Slope of selection curve
hnd.l50        59.466      1 ;[53          ] L50 of selection curve
hnd.fl983      0.075431748  1 ;[0.0756208 ] Partial F
hnd.fl985      0.10155915   1 ;[0.0800624 ]
hnd.fl986      0.084480353  1 ;[0.0642485 ]
hnd.fl987      0.015452647  1 ;[0.0177128 ]
hnd.fl988      0.011670499  1 ;[0.0122281 ]
hnd.fl989      0.021178084  1 ;[0.0238063 ]
hnd.fl990      0.016107895  1 ;[0.0146502 ]
hnd.fl991      0.014208944  1 ;[0.0149757 ]
hnd.fl992      0.014069016  1 ;[0.015031  ]
hnd.fl993      0.019265681  1 ;[0.0211967 ]
hnd.fl994      0.025607546  1 ;[0.0236036 ]
hnd.fl995      0.019794781  1 ;[0.0138551 ]
hnd.fl996      0.018006997  1 ;[0.0140966 ]
hnd.fl997      0.023647875  1 ;[0.0230576 ]
hnd.fl998      0.027326092  1 ;[0.0360075 ]
hnd.fl999      0.048321997  1 ;[0.0518532 ]
```

```
;Longline
lng.slope      0.042876211  1 ;[0.0403351 ] Slope of selection curve
lng.l50        60          1 ;[53          ] L50 of selection curve
lng.fl983      0.12865     1 ;[0.1          ] Partial F
lng.fl985      0.066131775  1 ;[0.0603888 ]
lng.fl986      0.10555025   1 ;[0.118796  ]
lng.fl987      0.123474     1 ;[0.13        ]
lng.fl988      0.131085     1 ;[0.15        ]
lng.fl989      0.070260789  1 ;[0.0994491 ]
lng.fl990      0.015243247  1 ;[0.0181273 ]
lng.fl991      0.013427487  1 ;[0.0153615 ]
lng.fl992      0.012314316  1 ;[0.0146599 ]
lng.fl993      0.019742464  1 ;[0.0228395 ]
lng.fl994      0.038675033  1 ;[0.0411349 ]
lng.fl995      0.074166473  1 ;[0.062821  ]
lng.fl996      0.080220102  1 ;[0.0752675 ]
lng.fl997      0.075102682  1 ;[0.101545  ]
lng.fl998      0.077044687  1 ;[0.112065  ]
lng.fl999      0.078645937  1 ;[0.109276  ]
```

```
;Norwegian trawl
nor.slope      0.044906956  1 ;[0.0395656 ] Slope of selection curve
nor.l50        53.872      1 ;[52          ] L50 of selection curve
nor.fl983      0.14628     1 ;[0.1          ] Partial F
nor.fl985      0.08535     1 ;[0.05        ]
nor.fl986      0.153374     1 ;[0.13        ]
nor.fl987      0.34792971   1 ;[0.425498  ]
nor.fl988      0.226198     1 ;[0.14        ]
nor.fl989      0.09457     1 ;[0.1          ]
nor.fl990      0.035952     1 ;[0.04        ]
nor.fl991      0.021464     1 ;[0.02        ]
nor.fl992      0.027309     1 ;[0.03        ]
nor.fl993      0.04245     1 ;[0.05        ]
nor.fl994      0.099638     1 ;[0.07        ]
nor.fl995      0.130242     1 ;[0.07        ]
nor.fl996      0.127498     1 ;[0.07        ]
nor.fl997      0.133395     1 ;[0.15        ]
nor.fl998      0.142668     1 ;[0.18        ]
nor.fl999      0.12935     1 ;[0.1          ]
```

Continued.....

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;Russian trawl
rus.slope      0.06457127  1 ;[0.0564928 ] Slope of selection curve
rus.l50        47.526612   1 ;[50.1759   ] L50 of selection curve
rus.fl1983     0.04302968  1 ;[0.0444292 ] Partial F
rus.fl1985     0.081625    1 ;[0.05      ]
rus.fl1986     0.18336     1 ;[0.1       ]
rus.fl1987     0.18606     1 ;[0.1       ]
rus.fl1988     0.208233    1 ;[0.17      ]
rus.fl1989     0.145894    1 ;[0.14      ]
rus.fl1990     0.055542    1 ;[0.03      ]
rus.fl1991     0.079646    1 ;[0.07      ]
rus.fl1992     0.08303     1 ;[0.05      ]
rus.fl1993     0.111516    1 ;[0.06      ]
rus.fl1994     0.16099     1 ;[0.1       ]
rus.fl1995     0.239083    1 ;[0.13      ]
rus.fl1996     0.260028    1 ;[0.18      ]
rus.fl1997     0.36594     1 ;[0.36      ]
rus.fl1998     0.42816     1 ;[0.24      ]
rus.fl1999     0.332266    1 ;[0.22      ]

;Overfishing
ovr.slope      0.04        0 ; Slope of selection curve
ovr.l50        52          0 ; L50 of selection curve
ovr.fl1983     0           0 ; Partial F
ovr.fl1985     0           0
ovr.fl1986     0           0
ovr.fl1987     0           0
ovr.fl1988     0           0
ovr.fl1989     0           0
ovr.fl1990     0.03        0
ovr.fl1991     0.07        0
ovr.fl1992     0.08        0
ovr.fl1993     0.03        0
ovr.fl1994     0.015       0
ovr.fl1995     0           0
ovr.fl1996     0           0
ovr.fl1997     0           0
ovr.fl1998     0           0
ovr.fl1999     0           0

;survey names
;1 lofac      - Lofoten acoustic (1985-2000)
;2 baltr      - Barents Sea trawl (1983-1993)
;3 balac      - Barents Sea acoustic (1983-1993)
;4 svatr      - Svalbard bottom trawl survey (1987-1999) not in use at present
;5 ba2ac      - Barents Sea acoustic (1994-2000)
;6 ba2tr      - Barents Sea trawl (1994-2000)
;7 rustr      - Russian autumn bottom trawl survey - 1982-1999
;8 nortr      - Norwegian summer (autumn) survey - bottom trawl (1995-1999)
;Survey catchability parameter names
;04 cbt       - Catchability
;01 b0        - Exponent (for power fit) or constant (for linear fit)
;02 slope     - Slope
;03 l50       - L50

;Barents Sea trawl (1983-1993)
;baltr.cbt    0.4          1 ;Catchability
;baltr.b0     1            0 ;b0
;baltr.slope  0.05         1 ;Slope
;baltr.l50    20.0         1 ;L50

```

Continued.....

;Barents Sea trawl (1994-2000)

ba2tr.cbt	0.4450967	1	;	[0.45344]	Catchability
ba2tr.b0	1	0	;			b0
ba2tr.slope	0.05	0	;			Slope
ba2tr.l50	5	0	;			L50

;Lofoten acoustic (1985-2000)

lofac.cbt	0.6353	1	;	[0.5]	Catchability
lofac.b0	1	0	;			b0
lofac.slope	0.05	0	;			Slope
lofac.l50	5	0	;			L50

;Barents Sea acoustic (1983-1993)

;balac.cbt	0.666635	1	;	Catchability
;balac.b0	1	0	;	b0
;balac.slope	0.05	1	;	Slope
;balac.l50	20.0	1	;	L50

;Barents Sea acoustic (1994-2000)

ba2ac.cbt	0.43007066	1	;	[0.43503]	Catchability
ba2ac.b0	1	0	;			b0
ba2ac.slope	0.05	0	;			Slope
ba2ac.l50	5	0	;			L50

;Russian autumn bottom trawl survey - 1982-1999

rustr.cbt	0.13388	1	;	[0.2]	Catchability
rustr.b0	1	0	;			b0
rustr.slope	0.26339398	1	;	[0.141564]	Slope
rustr.l50	1	1	;	[1]	L50

;Norwegian summer (autumn) survey - bottom trawl (1995-1999)

nortr.cbt	0.63386493	1	;	[0.62168]	Catchability
nortr.b0	1	0	;			b0
nortr.slope	0.05	0	;			Slope
nortr.l50	5	0	;			L50

APPENDIX 2

switches		value	optimize
;Growth parameter for each year			
growth.1983	10.0	1 ;12.448	
growth.1984	10.0	1 ;12.7195	
growth.1985	10.0	1 ;8.36056	
growth.1986	10.0	1 ;8.41845	
growth.1987	10.0	1 ;5.14479	
growth.1988	8.21156	1	
growth.1989	15.0103	1	
growth.1990	9.44654	1	
growth.1991	9.95202	1	
growth.1992	4.91617	1	
growth.1993	8.73308	1	
growth.1994	8.9534	1	
growth.1995	7.79938	1	
growth.1996	10.9841	1	
growth.1997	11.1448	1	
growth.1998	11.2447	1	
growth.1999	11.5763	1	
growth.2000	9.6	1	
;Growth distribution parameters			
growth.k0	-0.072783	0 ;Growth distribution param. k0	
growth.k1	1.0	1 ;Growth distribution param. k1 0.540675	
growth.exponent	0	0	
growth.ratio	0.8	1 ;Ratio of Mature/immature growth	
;Cannibalism parameters			
cann_beta	0.00103295	0 ;Cannibalism parameter beta	
cann_gamma	0.0001	0 ;Cannibalism parameter gamma	
cann_delta	0.309428	0 ;Cannibalism parameter delta	
cann_alpha	7e-06	0 ;Cannibalism parameter alpha	
;Quarterly natural residual mortality of immature fish (in 3 length intervals)			
imm.mort1	0.05	0 ;Quart. imm mortality length 1	
imm.mort2	0.05	0 ;Quart. imm mortality length 2	
imm.mort3	0.05	0 ;Quart. imm mortality length 3	
;Number of immature fish in startyear of age x (10^7)			
imm.n_age3	15.0	1 ;24.3579	
imm.n_age4	13.8161	1	
imm.n_age5	6.61219	1	
imm.n_age6	4.53659	1	
imm.n_age7	2.80878	1	
imm.n_age8	2.62073	1	
imm.n_age9	0.364292	1	
imm.n_age10	0	0	
;Mean length (cm) of immature fish in startyear at age x			
imm.l_age3	34.8	0	
imm.l_age4	45.9	0	
imm.l_age5	54.5	0	
imm.l_age6	62.7	0	
imm.l_age7	73.1	0	
imm.l_age8	78.6	0	
imm.l_age9	85	0	
imm.l_age10	90	0	

Continued.....

```
;Standard Deviation of mean length of immature fish in startyear at age x
imm.d_age3      4.2      0
imm.d_age4      4.7      0
imm.d_age5      4.3      0
imm.d_age6      5.2      0
imm.d_age7      4.2      0
imm.d_age8      6.8      0
imm.d_age9      13.7     0
imm.d_age10     13.5     0
```

```
;Maturation parameters
maturation.slope 0.03      0 ;Maturation, slope
maturation.l50   78.44     0 ;Maturation, L50
```

```
;Number of minimum-age fish at start of year x (10^7)
n_minage.1984    53.4259   1
n_minage.1985    60.818    1
n_minage.1986    60.105    1 ;123.105
n_minage.1987    46.4093   1
n_minage.1988    35.5      1
n_minage.1989    42.4426   1 ;22.4426
n_minage.1990    37.6845   1
n_minage.1991    54.2067   1
n_minage.1992    89.8773   1
n_minage.1993    60.867    1 ;115.867
n_minage.1994    60.185    1 ;106.185
n_minage.1995    61.5676   1
n_minage.1996    41.7543   1
n_minage.1997    69.3211   1
n_minage.1998    84.7229   1
n_minage.1999    48.2519   1
n_minage.2000    57.9294   1
```

```
;Mean length of minimum-age fish at start of year x
l_minage.1984    35.8      1
l_minage.1985    50.3      1 ;40.3
l_minage.1986    44.4      1 ;34.4
l_minage.1987    41.8      1 ;31.8
l_minage.1988    39.7      1 ;29.7
l_minage.1989    44.7      1 ;34.7
l_minage.1990    39.4      1
l_minage.1991    41.6      1
l_minage.1992    41.3      1
l_minage.1993    35.9      1
l_minage.1994    30.5      1
l_minage.1995    29.9      1
l_minage.1996    28.1      1
l_minage.1997    28.0      1
l_minage.1998    28.7      1
l_minage.1999    29.0      1
l_minage.2000    28.7      1
```

Continued.....

;Standard deviation of mean length of minimum-age fish at start of year x

d_minage.1984	4.3	0
d_minage.1985	5.1	0
d_minage.1986	4.4	0
d_minage.1987	3.5	0
d_minage.1988	3.1	0
d_minage.1989	3.4	0
d_minage.1990	6.8	0
d_minage.1991	5.8	0
d_minage.1992	6.5	0
d_minage.1993	4.4	0
d_minage.1994	5.0	0
d_minage.1995	5.9	0
d_minage.1996	5.0	0
d_minage.1997	3.9	0
d_minage.1998	4.4	0
d_minage.1999	4.2	0
d_minage.2000	4.1	0

;Quarterly natural residual mortality of mature fish (in 3 length intervals)

mat.mort1	0.05	0 ;Quart. mat mortality length 1
mat.mort2	0.05	0 ;Quart. mat mortality length 2
mat.mort3	0.05	0 ;Quart. mat mortality length 3

;Number of mature fish in startyear of age x (10⁷)

mat.n_age4	0.94	0
mat.n_age5	0.81	0
mat.n_age6	1.49	0
mat.n_age7	2.53	0
mat.n_age8	2.77	0
mat.n_age9	0.44	0
mat.n_age10	0.11	0
mat.n_age11	0.05	0
mat.n_age12	0.02	0

;Mean length (cm) of mature fish in startyear at age x

mat.l_age4	51.0	0
mat.l_age5	59.6	0
mat.l_age6	71.1	0
mat.l_age7	79.0	0
mat.l_age8	88.2	0
mat.l_age9	97.3	0
mat.l_age10	100.0	0
mat.l_age11	105.0	0
mat.l_age12	110.0	0

;Standard Deviation of mean length of mature fish in startyear at age x

mat.d_age4	1.06835	0
mat.d_age5	1.05602	0
mat.d_age6	1.01149	0
mat.d_age7	1.82767	0
mat.d_age8	2.56627	0
mat.d_age9	4.00303	0
mat.d_age10	7.15294	0
mat.d_age11	7.33135	0
mat.d_age12	9.03202	0

Continued.....

```

;fleet names
;11 dan - Danish seine
;12 gil - Gillnet
;13 hnd - Handline
;14 lng - Longline
;15 nor - Norwegian trawl
;16 rus - Russian trawl
;17 trd - Third countries
;18 ovr - Overfishing

;Catches, selection parameters
;05 slope
;06 l50

;Danish seine
dan.slope      0.0607076      1 ;Slope of selection curve
dan.l50        38.9944       1 ;L50 of selection curve 48.9944
dan.f1983      0.0587794     1 ;Partial F
dan.f1985      0.0219238     1
dan.f1986      0.0221278     1
dan.f1987      0.0104634     1
dan.f1988      0.0181976     1
dan.f1989      0.0176029     1
dan.f1990      0.00826144    1
dan.f1991      0.00635922    1
dan.f1992      0.00595641    1
dan.f1993      0.0086952     1
dan.f1994      0.0133794     1
dan.f1995      0.0230026     1
dan.f1996      0.0550674     1
dan.f1997      0.0704295     1
dan.f1998      0.0732092     1
dan.f1999      0.0466631     1

;Gillnet
gil.p0         0.0           0 ;Parameters for bell-shaped selection curve
gil.p1         0.2           1 ;
gil.p2         1.0           0 ;
gil.p3         0.03          1 ;
gil.p4         0.1           1 ;
gil.f1983      0.5           1 ;Partial F
gil.f1985      0.45          1
gil.f1986      0.3           1
gil.f1987      0.2           1
gil.f1988      0.3           1
gil.f1989      0.3           1
gil.f1990      0.0946737     1
gil.f1991      0.1           1
gil.f1992      0.074         1
gil.f1993      0.12          1
gil.f1994      0.13          1
gil.f1995      0.27          1
gil.f1996      0.30          1
gil.f1997      0.3           1
gil.f1998      0.2           1
gil.f1999      0.2           1

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Continued.....

;Handline		
hnd.slope	0.0405734	1 ;Slope of selection curve
hnd.l50	53.0	1 ;L50 of selection curve
hnd.f1983	0.0756208	1 ;Partial F
hnd.f1985	0.0800624	1
hnd.f1986	0.0642485	1
hnd.f1987	0.0177128	1
hnd.f1988	0.0122281	1
hnd.f1989	0.0238063	1
hnd.f1990	0.0146502	1
hnd.f1991	0.0149757	1
hnd.f1992	0.015031	1
hnd.f1993	0.0211967	1
hnd.f1994	0.0236036	1
hnd.f1995	0.0138551	1
hnd.f1996	0.0140966	1
hnd.f1997	0.0230576	1
hnd.f1998	0.0360075	1
hnd.f1999	0.0518532	1
;Longline		
lng.slope	0.0403351	1 ;Slope of selection curve
lng.l50	43.0	1 ;L50 of selection curve 53.0
lng.f1983	0.1	1 ;Partial F
lng.f1985	0.0603888	1
lng.f1986	0.118796	1
lng.f1987	0.13	1
lng.f1988	0.15	1
lng.f1989	0.0994491	1
lng.f1990	0.0181273	1
lng.f1991	0.0153615	1
lng.f1992	0.0146599	1
lng.f1993	0.0228395	1
lng.f1994	0.0411349	1
lng.f1995	0.062821	1
lng.f1996	0.0752675	1
lng.f1997	0.101545	1
lng.f1998	0.112065	1
lng.f1999	0.109276	1
;Norwegian trawl		
nor.slope	0.0395656	1 ;Slope of selection curve
nor.l50	42.0	1 ;L50 of selection curve 52.0
nor.f1983	0.1	1 ;Partial F
nor.f1985	0.05	1
nor.f1986	0.13	1
nor.f1987	0.425498	1
nor.f1988	0.14	1
nor.f1989	0.1	1
nor.f1990	0.04	1
nor.f1991	0.02	1
nor.f1992	0.03	1
nor.f1993	0.05	1
nor.f1994	0.07	1
nor.f1995	0.07	1
nor.f1996	0.07	1
nor.f1997	0.15	1
nor.f1998	0.18	1
nor.f1999	0.10	1

Continued.....

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;Russian trawl
rus.slope      0.0564928    1 ;Slope of selection curve
rus.l50        40.1759     1 ;L50 of selection curve 50.1759
rus.fl1983     0.0444292   1 ;Partial F
rus.fl1985     0.05        1
rus.fl1986     0.1         1
rus.fl1987     0.1         1
rus.fl1988     0.17        1
rus.fl1989     0.14        1
rus.fl1990     0.03        1
rus.fl1991     0.07        1
rus.fl1992     0.05        1
rus.fl1993     0.06        1
rus.fl1994     0.1         1
rus.fl1995     0.13        1
rus.fl1996     0.18        1
rus.fl1997     0.36        1
rus.fl1998     0.24        1
rus.fl1999     0.22        1

;Overfishing
ovr.slope      0.04        0 ;Slope of selection curve
ovr.l50        52          0 ;L50 of selection curve
ovr.fl1983     0           0 ;Partial F
ovr.fl1985     0           0
ovr.fl1986     0           0
ovr.fl1987     0           0
ovr.fl1988     0           0
ovr.fl1989     0           0
ovr.fl1990     0.03        0
ovr.fl1991     0.07        0
ovr.fl1992     0.08        0
ovr.fl1993     0.03        0
ovr.fl1994     0.015       0
ovr.fl1995     0           0
ovr.fl1996     0           0
ovr.fl1997     0           0
ovr.fl1998     0           0
ovr.fl1999     0           0

;survey names
;1 lofac      - Lofoten acoustic (1985-2000)
;2 baltr      - Barents Sea trawl (1983-1993)
;3 balac      - Barents Sea acoustic (1983-1993)
;4 svatr      - Svalbard bottom trawl survey (1987-1999) not in use at present
;5 ba2ac      - Barents Sea acoustic (1994-2000)
;6 ba2tr      - Barents Sea trawl (1994-2000)
;7 rustr      - Russian autumn bottom trawl survey - 1982-1999
;8 nortr      - Norwegian summer (autumn) survey - bottom trawl (1995-1999)
;Survey catchability parameter names
;04 cbt       - Catchability
;01 b0        - Exponent (for power fit) or constant (for linear fit)
;02 slope     - Slope
;03 l50       - L50
;Barents Sea trawl (1983-1993)
;baltr.cbt    0.4          1 ;Catchability
;baltr.b0     1            0 ;b0
;baltr.slope  0.05         1 ;Slope
;baltr.l50    20.0         1 ;L50

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Continued.....

;Barents Sea trawl (1994-2000)

ba2tr.cbt	0.45344	1 ;Catchability
ba2tr.b0	1	0 ;b0
ba2tr.slope	0.05	0 ;Slope
ba2tr.l50	5	0 ;L50

;Lofoten acoustic (1985-2000)

lofac.cbt	0.5	1 ;Catchability
lofac.b0	1	0 ;b0
lofac.slope	0.05	0 ;Slope
lofac.l50	5	0 ;L50

;Barents Sea acoustic (1983-1993)

;balac.cbt	0.666635	1 ;Catchability
;balac.b0	1	0 ;b0
;balac.slope	0.05	1 ;Slope
;balac.l50	20.0	1 ;L50

;Barents Sea acoustic (1994-2000)

ba2ac.cbt	0.43503	1 ;Catchability
ba2ac.b0	1	0 ;b0
ba2ac.slope	0.05	0 ;Slope
ba2ac.l50	5	0 ;L50

;Russian autumn bottom trawl survey - 1982-1999

rustr.cbt	0.2	1 ;Catchability
rustr.b0	1	0 ;b0
rustr.slope	0.141564	1 ;Slope
rustr.l50	1	1 ;L50

;Norwegian summer (autumn) survey - bottom trawl (1995-1999)

nortr.cbt	0.62168	1 ;Catchability
nortr.b0	1	0 ;b0
nortr.slope	0.05	0 ;Slope
nortr.l50	5	0 ;L50